G. S.

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RELEASE FORM

NAME OF AUTHOR. Richard Charles Shelford

TITLE OF THESIS. The Geomorphology of the Weed Creek Basin, Alberta, Canada

DEGREE FOR WHICH THESIS WAS PRESENTED.

Master of Science

YEAR THIS DEGREE GRANTED. Spring 1975

THE UNIVERSITY OF ALBERTA

THE GEOMORPHOLOGY OF THE
WEED CREEK BASIN, ALBERTA, CANADA

by

© RICHARD CHARLES SHELFORD

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

OF MASTER OF SCIENCE

DEPARTMENT OF GEOGRAPHY

EDMONTON, ALBERTA

SPRING, 1975

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THE UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled, "The Geomorphology of the Weed Creek Basin, Alberta, Canada" submitted by Richard C. Shelford in partial fulfilment of the requirements for the degree of Master of Science.

This thesis is dedicated

to my mother

Ellen

ABSTRACT

This geographic study of the Weed Creek basin provides further details concerning the post-glacial history of the North Saskatchewan river system. It examines and analyses terrace distribution within the basin and correlates the terraces with those of Whitemud Creek and the North Saskatchewan River in the Edmonton area.

The region's Upper Cretaceous bedrock is overlain by a variety of fluviatile and Laurentide glacial and glacio-lacustrine deposits on which chernozemic and podzolic soils are developing under a parkland vegetation and a continental climate.

There are four cyclic terraces in the basin; all are depositional and alluvial in character. The terrace levels, lower, middle, upper and higher, were differentiated on the bases of continuity, mapping, and percentage-height analysis of former bedload-bedrock contacts and terrace tread surfaces thus avoiding the problems of using absolute-height data.

A regional correlation with the Whitemud Creek and the North Saskatchewan valley terraces in the Edmonton area is proposed. The existence of a higher terrace is confirmed. An extinct bison scapula from the lower terrace level was dated at 2765±90 14C yr BP with the middle, upper and higher terraces being older. The difference in the absolute date

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obtained for the lower terrace here compared with those of the North Saskatchewan is due to the time-lag required to develop terraces in tributaries following baselevel lowering of trunk streams. These changes in baselevel of the North Saskatchewan have been the principal controls effecting the development of Weed Creek.

ACKNOWLEDGEMENTS

I take this opportunity to thank my Supervisor, Dr. I.A. Campbell, for his guidance and constructive criticism during all phases of the study. His assistance, both in the field and in the written preparation of the thesis is greatly appreciated. Thanks also to the many Geography graduate students who assisted me so ably with my fieldwork. I have to thank Mr. J. Chesterman and staff for their very high quality of technical work in producing the final copies of maps under sometimes less than ideal circumstances. The assistance given by Mr. G. Lester and his staff is also greatly appreciated. Thanks to Lelde Atvars who spent long hours typing the draft and final copies of the thesis. The help of Mr. Ron Whistance-Smith and his staff--University Map Collection, Geography Dept., is acknowledged. The always present encouragement of relatives and close friends, which has been of tremendous support to me during every stage of my University career is also acknowledged and sincerely appreciated.

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PHOTO PLATES OF STUDY AREA

INTRODUCTION

Investigations into the fluvial geomorphology of small watersheds in Alberta are rare. McPherson (1968) discovered that few studies exist which describe the historical evolution and landform assemblages of the river valleys in Western Canada. Exceptions to these are McPherson (1966, 1968), Stalker (1968), Westgate (1969), and Rains (1969).

The purpose of this study is to extend the knowledge of the regional geomorphology of the North Saskatchewan River system in the Edmonton area and the region's post-glacial history. The study deals with the development of a post-glacial geomorphic chronology of the Weed Creek basin through detailed analysis of its terraces and other geomorphic and geologic features.

The main objectives are:

1. To measure certain valley landform features and characteristics of the Weed Creek basin;
2. To interpret the post-glacial geomorphic history of the basin; and
3. To examine correlations with the Whitemud basin and the North Saskatchewan river in the Edmonton area.

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The inter-connecting nature of Westgate's (1969) study on the North Saskatchewan river near Edmonton and Rain's (1969) analysis in the Whitemud basin, will add to the knowledge of the major regional geomorphic chronology.

The Weed Creek and Whitemud basins are of similar size and are both tributaries of the North Saskatchewan river. They should therefore possess morphologic similarities.

CHAPTER 1

THE STUDY AREA

Weed Creek is a south bank tributary of the North Saskatchewan river entering the main stream approximately eleven miles west of Devon, near Edmonton, Alberta (Fig. 1:1). The ninety-five square mile Weed Creek basin lies on the western fringe of the Eastern Alberta Plains (Atlas of Alberta, 1969). The basin is bounded by 113°45' - 114°15' W. longitude, and 53°00' - 53°32' N. latitude, and consists of townships 45 - 51 from the west half of range 26 west of the 4th meridian westward to range 2 west of the 5th meridian. The sixteen mile long basin, ten miles across at its widest part, is crossed by Highway 39 which leads to Calmar. Thorsby is the only large settlement within the basin.

Geology

Bedrock in the area is mainly Upper Cretaceous Edmonton formation (Taylor, Mathews and Kupsch, 1964). Sediments of this formation consist of soft, grey to white-weathering, friable feldspathic sandstone, bentonitic silt, bentonic beds, and grey and brown shales; coal beds and carbonaceous shales and nodular ironstone beds are common (Williams and Berg, 1964). A number of researchers (Allan and Sanderson, 1945; Ower, 1960; Srivastava and

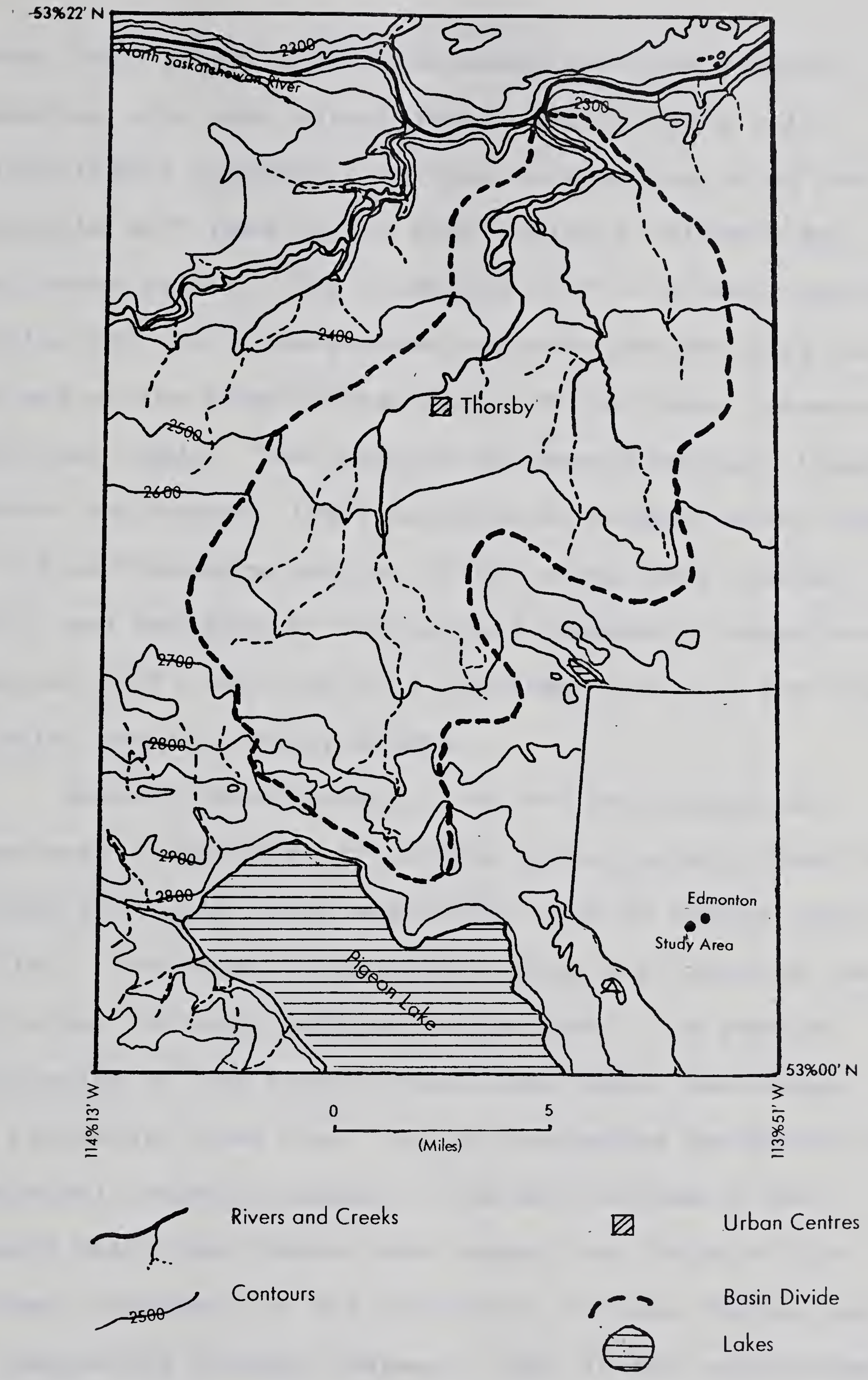

Figure 1:1 The Study Area

Binda,1968; Irish, 1970) have subdivided the Edmonton Formation into many stratigraphic units (Table 1:1), Eliott (1960) suggests a twofold subdivision using the Kneehills tuff zone as the most reliably dateable and continuous marker. The Kneehills tuff is a hard, uniform, massive and very fine-grained volcanic ash bed that marks the end of the Maestichtian stage of the Upper Cretaceous (Ritchie, 1960). The Tertiary Paskapoo Formation (Taylor, Mathews and Kupsch, 1964) outcrops at several spots mainly in the southwestern section of the study area (Ozoray, 1972), and consists of fluvial and lacustrine deposits of massive, buff, soft and hard sandstone and grey and green, friable, normally silty shales.

Bedrock stratigraphy, type and topography are important in any study of fluvial geomorphology since they control to a very large extent the rate of stream down-cutting. The bedrock topography (Fig. 1:2) depicts the preglacial drainage pattern in the area. The eastern tributaries of the present Weed Creek basin now occupy the preglacial Weed Creek valley (hereafter designated the preglacial Thorsby thalweg). The main stream of the present Weed Creek basin cuts across the divide of the southern tributary of the preglacial Warberg thalweg and the preglacial Thorsby thalweg. Only in the northernmost extent does the present stream follow the old preglacial Thorsby thalweg.

TABLE 1:1. SUBDIVISIONS OF TERTIARY AND CRETACEOUS BEDROCK

<table>
<tr><th colspan="2">after Allan and Sanderson (1945)</th><th colspan="2">after Ower (1960)</th><th colspan="2">after Srivastava (1968)</th><th colspan="2">Irish (1969)</th></tr>
<tr><td colspan="2">Paskapoo Formation</td><td colspan="2">Paskapoo Formation</td><td colspan="2">Paskapoo Formation</td><td colspan="2">Paskapoo</td></tr>
<tr><td rowspan="10">Edmonton Formation</td><td rowspan="2">Upper Edmonton</td><td rowspan="10">Edmonton Formation</td><td rowspan="2">member E</td><td rowspan="10">Edmonton Formation</td><td>Nevis member</td><td rowspan="2">Formation</td><td rowspan="2">Scollard Member</td></tr>
<tr><td>Mamal-bearing member</td></tr>
<tr><td rowspan="2">Kneehills tuff zone</td><td rowspan="2">member D</td><td>Blackmud member</td><td rowspan="8">Edmonton Group</td><td>Battle Formation</td></tr>
<tr><td>Whitemud member</td><td>Whitemud Formation</td></tr>
<tr><td rowspan="2">Middle Edmonton</td><td>member C</td><td>Coaly member</td><td rowspan="6">Horseshoe Canyon Formation</td></tr>
<tr><td rowspan="3">member B</td><td>Tolman member</td></tr>
<tr><td>Drumheller marine tongue</td><td>Drumheller member</td></tr>
<tr><td rowspan="3">Lower Edmonton</td><td>Non-coaly member</td></tr>
<tr><td rowspan="2">member A</td><td>Coaly member</td></tr>
<tr><td>Transition member</td></tr>
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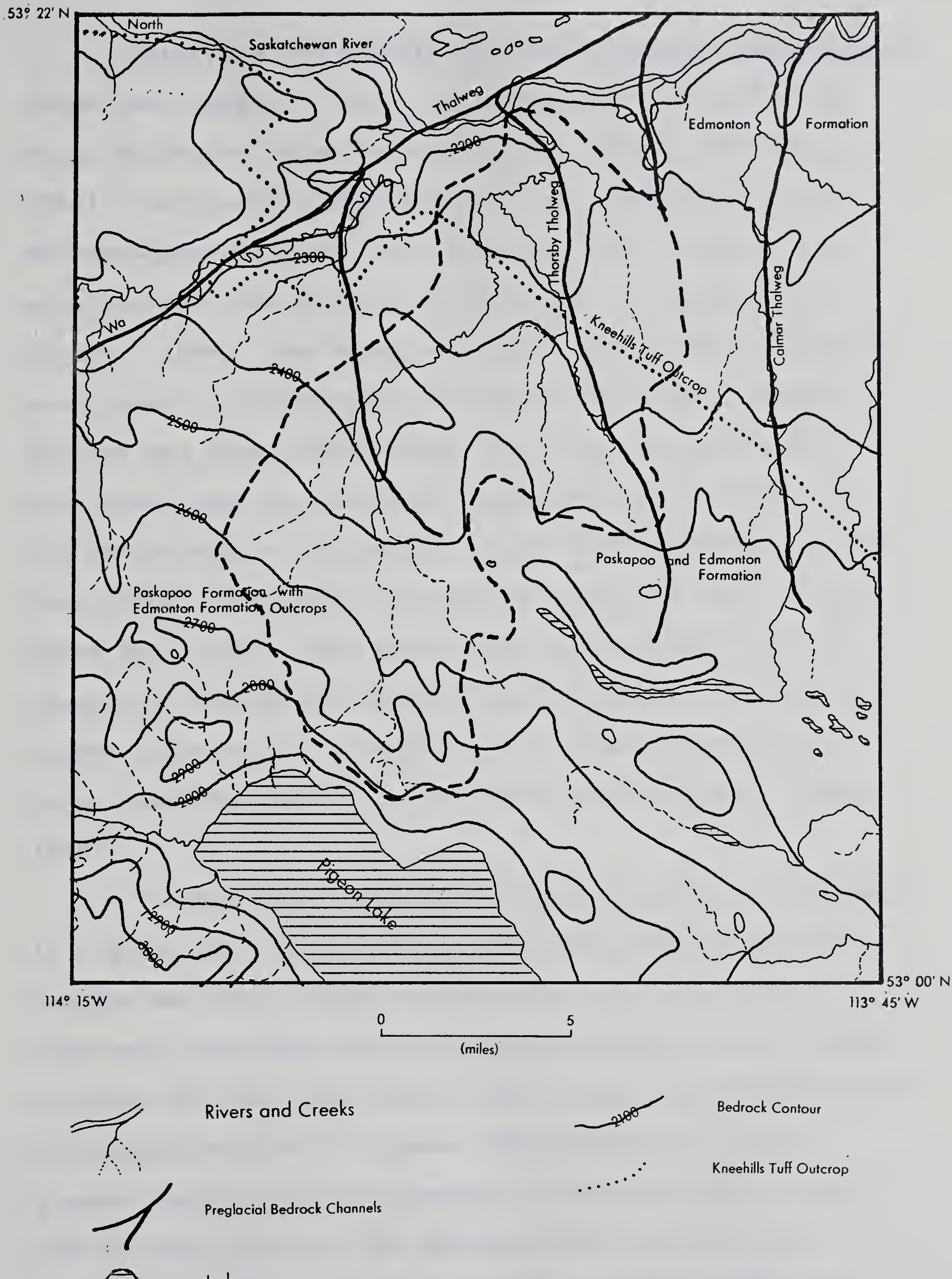

Figure 1:2 Bedrock Topography of Study Area

Source: Farvolen, 1963 and Carlson, 1971

Overlying the bedrock are the fluviatile Saskatchewan Sands and Gravels. These are mainly quartzite with the Rocky Mountains being the most likely source (Antoniuk, 1954). McConnell (1885) believed the deposits to be of Miocene-Quaternary age, but Tyrrell (1886) thought they were derived from Miocene conglomerates. Westgate and Bayrock (1964), and Westgate (1969), dated them as Pleistocene based on periglacial structures and faunal remains. Bayrock and Berg (1966) state that they are associated with more than one period of deposition and erosion but are definitely of preglacial origin and Pleistocene in age. Berg (1969) found that radiocarbon dating of wood in the sands and gravels gave dates older than 35,000 years BP (Geochron Laboratories GX-0106 and GX-0210). Further, a recent discovery of a vertebra of a Bison species indicates that the deposit is not older than Wisconsin (Berg, 1969).

The surficial geology of the study area is displayed in Figure 1:3. There are probably two tills in the area. Bayrock and Berg (1966) believe that only one till of Wisconsin age covers the area but observed a colour change at about 20 feet depth from brown to grey, and found lenses of stratified sand and gravel representing washing of glacial debris by running water. Westgate (1969), found two distinct tills in the Edmonton area separated by stratified sands up to 40 feet thick. Rains (1969), on

the basis of till fabric and colour, distinguished two tills in the Whitemud basin area immediately east of the Weed Creek basin. Though till does occur in the Weed Creek basin, no attempt was made to analyse the deposits.

The northern part of the study area (Fig. 1:3) is veneered with lacustrine deposits from the former Lake Edmonton (Bayrock and Hughes, 1962; Hughes, 1958). These deposits overlie the tills in the area. Just south of the North Saskatchewan River, the lacustrine deposits are overlain in sections by Early North Saskatchewan river alluvium (Bayrock and Hughes, 1962). Relief in the north is level to undulating; in the south it is rolling to hilly due to the surface expression of till in the form of hummocky dead-ice moraine (Fig. 1:3)(Bayrock and Hughes, 1962; Bowser, 1962; Lindsay <u>et al</u>, 1968; McPherson and Kathal, 1973).

Climate

The climate of the area, with relatively warm summers and cold winters, is continental with Dfc designation in the Köppen-Geiger classification (Strahler, 1969). The mean January, April, July and October temperatures (1931-1960) are 6^{o}-8^{o}F, 38^{o}-40^{o}F, 60^{o}-62^{o}F and 40^{o}F, respectively, and the average number of degree days above 42^{o}F is 2100-2300 (Atlas of Alberta, 1969). Thorsby has a mean annual temperature of 36.2^{o}F (Longley, 1968). The

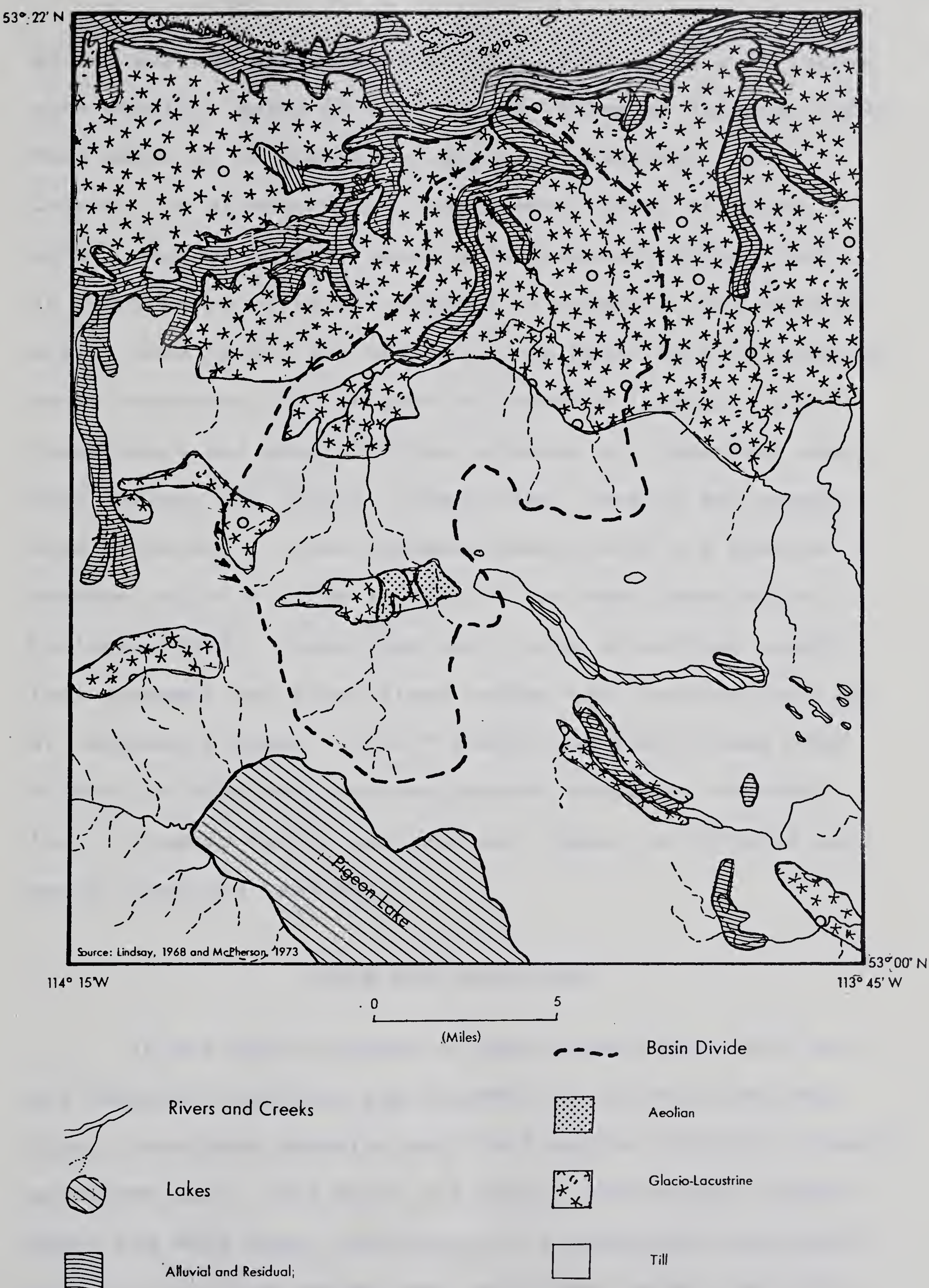

Figure 1:3 Surficial Geology of Study Area

annual average precipitation (1931-1960) is 18 - 20 inches with snowfall being 50 - 60 inches (Atlas of Alberta, 1969). Rain makes up 70 percent of all precipitation. The Chinook, an Alberta winter phenomenon, does, at times, affect central Alberta where a 40 Farenheit degree rise in temperature within 10 minutes is possible; the opposite shift, when Arctic air massed in the North West Territories pours southward, can be just as dramatic (Longley, 1967). Temperature and precipitation patterns are important since they reflect the runoff, stream-flow, erosion and vegetative patterns. In the Whitemud basin, with its similar subdued relief similar to that of the Weed Creek basin, Erxleben (1972), found that the yields of surface runoff from snowmelt and flash flows varied with density and type of vegetative cover. Runoff yields and flash flows were highest in crop and improved pasture sections; somewhat less in summer fallow sections and lowest in forested and partly forested sections.

Soils and Vegetation

In the south section of Weed Creek basin, till and the Paskapoo formation are present and in the north section, lacustrine deposits and the Edmonton Formation prevail with some till. The soils are mainly Chernozemic (Orthic Black and Dark Grey) indicative of a grassland environment and Podzolic (Grey Wooded and Dark Grey Wooded) depicting

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a Boreal forest environment. Small sections of Solonetzic (Black, Grey and Solodized) soils are also present. Pockets of Organic Soils occur in depressions and alluvial Regosols are found mainly along the stream and river banks (Lindsay _et al_, 1968). East of the 5th meridian, Bowser _et al_ (1962), describe similar soils which also reflect the nature of the underlying bedrock or surficial deposits and the vegetative cover (Fig. 1:4).

The Weed Creek basin lies in a transition zone between aspen parkland to the east and boreal mixed-wood forest to the west (Bird and Bird, 1967; LaRoi _et al_, 1967). Grasses in the area are primarily rough fescue. The tree species are mainly aspen poplar in the better drained sites and balsam poplar in the poorly drained sites. Willows are found in the wetter sites and silver willow in the drier sites. Many wild fruits exist--raspberry, chokecherry, saskatoon or serviceberry and pincherry. The conifers are mainly white and black spruce, jack pine and lodgepole pine. Mosses are mainly spaghnum. Labrador tea is the principle shrub growing in the bogs which, in addition, have willow, dwarf birch and alder growing around the edges (Lindsay _et al_, 1968). Moss (1955), noting the presence of chernozemic soils throughout the aspen parkland, believed that, for a considerable portion of Holocene time, grass must have been the dominant vegetation. He further postulated that, as a result of climatic and periodic burning, groves of aspen poplar have become established here in

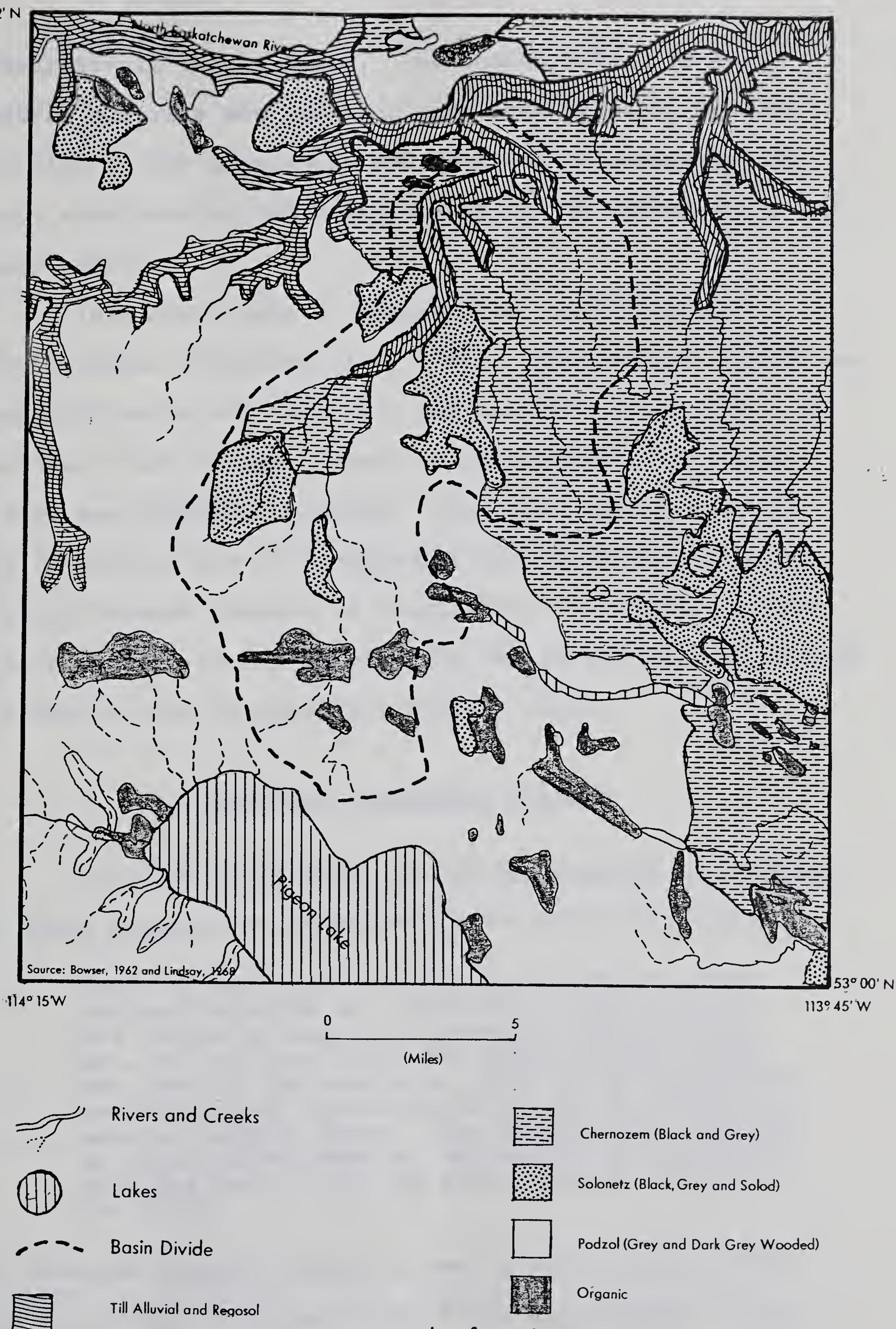

Figure 1:4 Soils of Study Area.

comparatively recent times. The Indian tribes of the western prairies and parkland area seem probably to have set fire to the grasslands and this was witnessed by the early missionaries and homesteaders in the region (Bird and Bird, 1967).

This broad belt of parkland is one of nature's battlegrounds (Bird and Bird, 1967). Apparently, vegetative stability could not have been maintained in this area, and continual flux between forest and grassland plant communities has probably occurred. This has significance for any interpretation of postglacial erosion and deposition history because changes in vegetation, for whatever cause, will have been partly responsible for stream regimen changes and debris load fluctuations (Rains, 1969).

Previous Geomorphic Studies

Palliser (1857-1860) in his *Observative Exploration of North America* was attracted by the river terraces:

> Until we approach close to the mountains these terrace deposits are confined to the valley of the larger streams, but gradually they spread out, and at last cover the whole country along the base of the mountains, filling up the hollows and valleys of the outer ranges to the depth of several hundred feet. This feature was observed at every point where we approached the mountains from the east, from the 49th parallel northward (p. 671).

He measured terrace levels in many of the larger rivers and found four terraces in the North Saskatchewan river

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near Rocky Mountain House at 25, 70, 180 and 300 feet above mean stream level, but made no attempt at dating or analysing them.

McPherson (1970) observed what he believed to be a series of discontinuous and non-paired terraces in the North Saskatchewan river between Saskatchewan Bridge and the Clive river. The maximum number of levels he identified at any one location was four. The highest level was 175 feet and the lowest was 13 feet above the present floodplain. A charcoal layer found in the same area, at the height of 18 feet above the present floodplain, has been radio-carbon dated at 9330$\pm$170 14C yr BP (Westgate and Dreimanis, 1967). McPherson consequently dates the terraces above 18 feet as being older than 9330$\pm$170 years BP.

Westgate (1969) observed four terrace levels along the North Saskatchewan river in the Edmonton area, but only completed detailed work on the lower two terraces. The average height of the terraces are 25, 65, 105 and 150 feet. He dates the 25 foot terrace at 5000 - 8500 years BP based on faunal remains, volcanic ash (Mazama) and a paleosol. The 65 foot terrace he dates at 10 - 11,000 years BP based on findings of similar faunal remains with Stalker's (1968) 65 foot terrace near Cochrane, Alberta.

Rains (1969) distinguished three terrace levels (upper, middle, and lower) in the Whitemud basin with a possible fourth higher level deposit. He discovered no

faunal remains or other dateable artifacts but was able to correlate his middle and lower terraces with Westgate's (1969) two lower terraces on the basis of height and continuity. The lower and middle terraces of the Whitemud basin exhibit a fining upwards sequence of deposits but the upper two terraces vary from this pattern.

Methodology of Research

Terraces are useful as guides to interpret the geologic and geomorphic history of a region. They represent the effects of river responses to tectonic or climatic changes or both, interspersed with periods of stability. The periods of change and stability produce an alternating aggradation and degradation sequence from which the river, with its changing regimes, cuts and shapes its terraces. A factor of major importance that affects the development of terraces is the geology of the river basin (Culling, 1957). The type of bedrock or surficial matter will affect the rate of erosion, river loads and sediments, channel and valley gradients and profiles through time.

Terraces are not always easily recognized and located. To develop a reliable chronology usually requires field and laboratory work. The distribution of terrace heights along the longitudinal profile of the river basin and the establishment of their paired or unpaired character must be determined. In order that these heights be of any meaning, a sequence of continuity must also be developed

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(Johnson, 1944). Continuity is the basic criterion of terrace correlations. Terrace heights of fairly equal altitude above stream level must display a pattern of continuity along the valley as well so that terraces formed at different times can be distinguished from each other. This is important since differing rates of erosion or deposition of colluvium on terrace remnants may lead to misinterpretation of terrace levels. Also, isolated flat spurs or terraces, paired or unpaired, may be produced at irregular points creating such a complexity that height analysis alone may not allow correlation and development of a reliable terrace chronology (Leonard and Frye, 1954). To avoid this, certain additional criteria must be followed to strengthen the sequence of continuity (Leopold, Wolman and Miller, 1964). These criteria are:

1. Stratigraphic discontinuities between terrace fills;
2. Particle-size analysis of terrace deposits;
3. Differences in primary and secondary structures;
4. The presence of artifacts, fossil fauna and flora, paleosols and frost features; and
5. Physiographic relation to other landforms--adjacent hills, moraines, old lake beds, etc.

This is important since the time sequence, rate, quantity and extent of aggradation and degradation may result in inset or overlapping relations of varying valley fills

from which the terraces may be cut.

The method of research hinged on the use of air photos (scale 1": 2640'). The photos were used extensively in the pre-field planning and in preparing a series of overlay maps of the basin; the main morphological features were delineated prior to field work. The photos were also used extensively in plotting the linear positions of terraces along the channel of the present stream. The planimetric plotting of the various terraces and other channel forms was achieved through the stereoscopic viewing of the air photos and height measurements were made with a stereometer. The fieldwork involved measurements of the stream gradient and the long and cross-valley profile measurements of terrace and bedrock heights. These heights were taken along the present stream channel using it as a base measure. The theodolite was used in determining gradients and cross-valley profiles and the Abney level (inclinometer) was used for terrace and bedrock height measurements. A few terrace gravels, lying on bedrock, were sampled but no sand, silt and clay deposits were sampled due to the lack of time available to complete this aspect of the field research adequately. Soils along the stream are mainly regosols and no attempt was made to analyse them. Statistical tests and graphs have been used in the differentiation, grouping and plotting of the terrace and bedrock heights. A hypsometric curve analysis

is presented for relief and basin development comparisons with the Whitemud basin. Finally, an extinct bison scapula was found in the deposits of one terrace and has been radio-carbon dated at 2765 ± 90 ^{14}C yr BP. This provides an absolute date for one terrace and assists in the regional analysis.

CHAPTER II

DEVELOPMENT AND CORRELATION OF RIVER TERRACES

Terraces are topographic platforms, benches, treads, flats or steps in river valleys that usually represent former levels of the valley floor or floodplain (Howard et al, 1968). They may be located at more-or-less constant elevations above the present floodplain or stream channel. In cross-section, terraces are usually separated by rises or scarps (for purposes of this thesis, the term 'terrace' will include both the scarp and tread features). The lower terraces are usually long and continuous, sometimes extending upstream or downstream for hundreds of feet; the upper terraces are usually isolated and discontinuous remnants.

The continuity of a given surface along the valley and an associated tendency for terrace remnants to occur at a uniform height above the present stream is a primary criterion for correlation (Leopold et al, 1964) but for correlation to be adequate and more reliable, the geologic or stratigraphic structure of the terraces should be studied (Frye and Leonard, 1954).

The literature on terrace formation is not only voluminous but authors differ in their description of such landforms based on either external causes, mode of formation

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or geologic structure. Though problems prevail, one thing is certain, that a particular landform develops from similar geomorphic processes irrespective of the region where those processes are or have been active. In the Western Canadian plains, the North Saskatchewan River valley has been formed since the melting of the last Wisconsin ice (Westgate, 1969). In the Edmonton area, four well developed terrace levels can be observed. The Weed Creek basin also displays several well-developed terraces. Being a tributary of the North Saskatchewan, its terraces should reflect, directly or indirectly, the influences of its trunk stream.

Causes of Terrace Formation

Leopold et al (1964) state that two fundamental controls, climatic and tectonic, are responsible for terrace development. A third, base-level control, may be also considered since it is not always directly dependant on the other two. Gilbert (1887) noted that the direct influences of the climatic elements of temperature and rainfall on the aggrading and degrading sequences of a river valley are comparatively simple but their indirect influence through vegetation is complex and in part opposed to the direct influences (Quinn, 1957). Langbein and Schumm (1958) observed that in a

> ...high-relief (humid) region, with a decrease in discharge (headwater precipitation), there is an increase in erosion on the slopes, down to a

> limit of about 10 - 24 inches, because of the discontinuous vegetation coverage (see Fig. 2:1). Below this limit further decrease in precipitation results in decreasing erosion until both variables reach zero. Downstream of the headwater area, beyond a certain 'neutral point' there will be an inverse rule: in a humid regime sedimentation rises with decreasing precipitation. In regions of extreme aridity (less than 10 inches), a rise in precipitation increases the erosion at that point, but still increases the sedimentation downstream, unless the stream enters a high rainfall belt. (Fairbridge, 1968.)

Now if an alternating sequence of aggradation and degradation processes within a stream, caused by climatic changes, takes place, each over a considerable length of time, many terraces of varying heights may be formed. In the North Saskatchewan River basin, such a sequence could have taken place.

Tectonic Control

Tectonic activity simply is the deformation of the earth's crust. For such activity to effect terrace formation, the heaving of the earth's crust should cause minimum rock deformation even when uplift is at a maximum. This kind of tectonic movement is known as Cymatogeny (King, 1959). If it takes place in an alternating sequence of positive (up) and negative (down) movements, terraces can be formed.

Also, tectonic activity due to isostatic rebound could have caused terrace formation. Farrand (1968) indi-

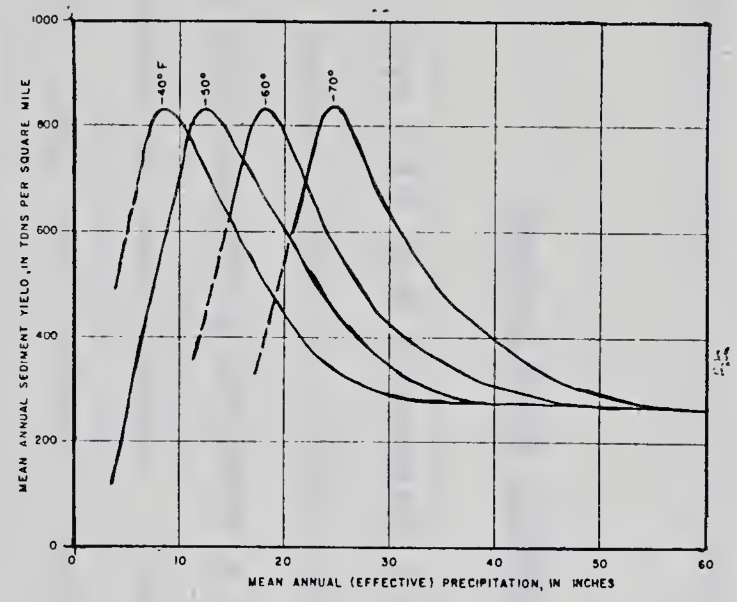

Figure 2:1 Relationship of Mean Annual Precipitation to Mean Annual Sediment

After Schumm, 1965

cates that areas covered by the greatest thicknesses of ice during glacial times are experiencing the greatest amount of post-glacial isostatic rebound. The extent of rebound depends mainly on the density and thickness of the ice sheet (Flint, 1971). Flint further states that if the Laurentide ice sheet reached maximum thicknesses of 3 km (1.88 miles), basining and subsequent uplift in central areas should approximate 1 km (0.63 miles). The rebound of such magnitude could initiate terrace formation in river valleys.

Base-Level Control

Base-level is the downward limit of valley deepening or the level below which a stream cannot erode. The flood-plain, which subsequently becomes a terrace, of a given epoch is related to base-level. Terraces reflect variations in base level and stream energy, two parameters which may change independently or together (Culling, 1957).

Where base-level fluctuations are in response to climatic changes, terrace formation directly controlled by base level movements such as in a tributary valley, will be formed synchronously with the terraces of its trunk stream. As the stream level of the main valley aggrades and degrades, with climatic change, building terraces, it controls the base-level fluctuations of the tributary stream. The Weed Creek basin and its trunk

stream, the North Saskatchewan River, have this relationship. Tributary streams should have the same number of terrace levels as the main valley and be comparable in mode of formation and geologic structure. Figure 2:2 shows such an idealized condition.

<u>Other Causes of River Terrace Formation</u>

Other factors beside climate, tectonic and base-level factors can cause terrace formation. They are: (1) Stream Piracy (Crosby, 1937); (2) Vegetation removal by non-climatic means; (3) Movement of extraneous material (Cotton, 1940; Frye and Leonard, 1954; Crampton, 1969; Ritter and Miles, 1973); and (4) Man induced (Born and Ritter, 1970).

There is no evidence of stream piracy in the Weed Creek basin. Vegetation removal by non-climatic means such as lightning fires probably has been very isolated and of minimal influence within the basin. Movement of extraneous material--colluvial and solifluction action--is probably present within the basin but such deposits are most likely along the back walls of the higher and older terraces which are somewhat removed from the stream channel. No evidence of colluvial or solifluction movement was noted in the terrace stratigraphies along the present stream. Man induced effects have been restricted to grazing and some grain growing which have minimum effects

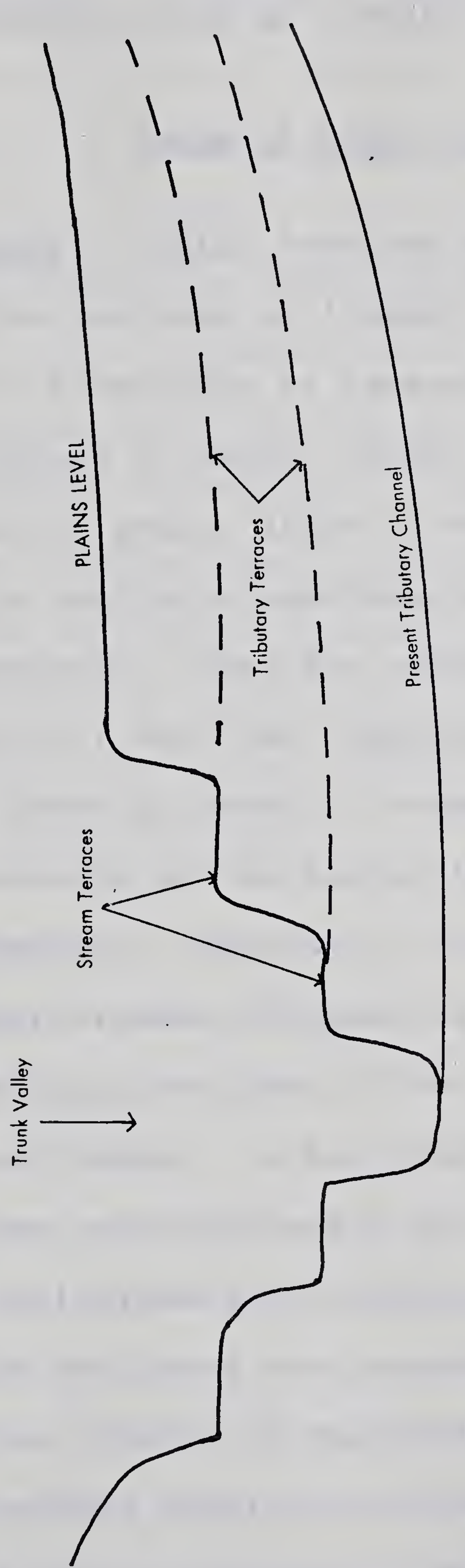

Figure 2:2 Relationship of Trunk and Tributary Stream Terraces

on erosion rates. No major project that could initiate terrace formation, such as damming, has been undertaken.

Types of River Terraces

Cyclic Terraces. Cyclic terraces are formed when a stream or river which has been in 'grade' for a long period of time builds a floodplain by lateral and vertical accretion. Grade, as defined by Mackin (1948), is "a state in which, over a period of years, slope is delicately adjusted to provide, with available discharge and with prevailing channel characteristics, just the velocity required for the transportation of the load supplied from the drainage basin." If after an epoch of stream stability one of the hydraulic controls of the stream is made to change, it becomes 'ungraded', resulting in rapid degradation; then the floodplain becomes incised, is abandoned and two terraces, on opposite sides of the valley, of equal elevation are formed. In any single episode of stability, the river does not continually cut downward but maintains a kind of equilibrium as it swings laterally, widening the valley at the level now representing that episode (Leopold et al, 1964). A repetition of this cycle in time would produce equal altitudinal twin-terraces at successively lower elevations within the valley. Terraces formed this way are called cyclic (Cotton, 1940, 1948) or paired (Leopold et al, 1964).

Some characteristics of cyclic terraces are their laterally opposing positions of roughly equal elevation and flat horizontal tread surfaces; longitudinal terraces or related channel gradients which are roughly parallel to the present stream profile; and an even thickness of alluvial terrace deposits on bedrock (Culling, 1957).

Rains (1969) indicated that possibly three major alternating periods of degradation and aggradation took place in the North Saskatchewan River valley. The cyclic nature of the Whitemud Creek terraces was based on such a sequence which controlled its base-level fluctuations. The Whitemud basin is also a north flowing tributary of the North Saskatchewan River valley. Some cyclic features are displayed in Figure 2:3.

<u>Non-Cyclic</u> <u>Terraces</u>. Non-cyclic terraces are formed when a relatively slowly degrading stream, i.e., one in shifting equilibrium (Mackin, 1948), still has the energy to erode or accrete laterally. The floodplain that is formed is not level in cross-section but slopes downward from one side of the valley to the other. Each succeeding lateral swing of the stream past a particular point will be at a succeeding lower elevation thus producing a floodplain that has two surfaces, each at opposite sides of the stream, at unequal elevation and both sloping downward from the valley sides towards the stream channel. Subsequent rapid degradation by the stream would cause entrench-

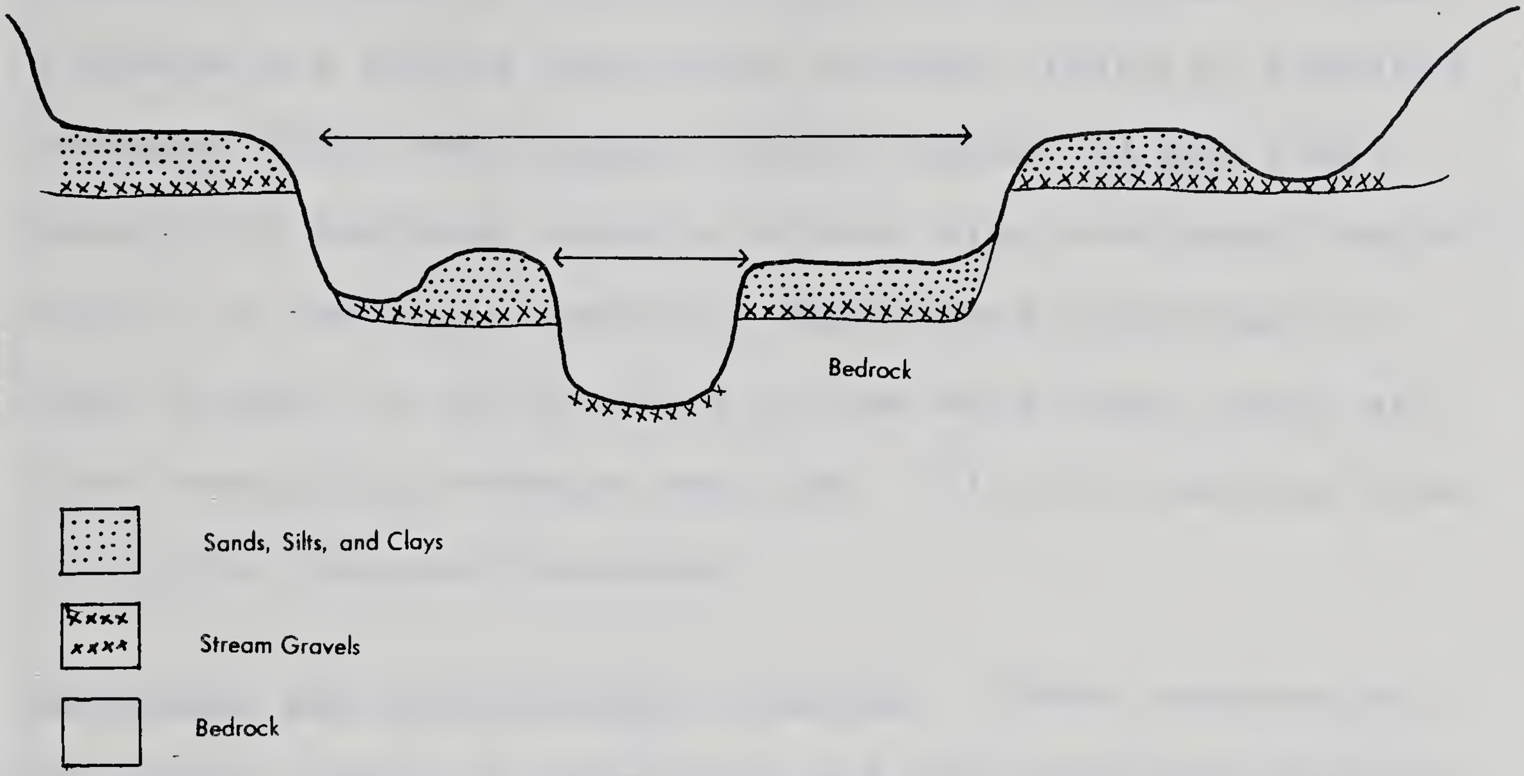

Figure 2:3 Cyclic Terraces (Depositional type)

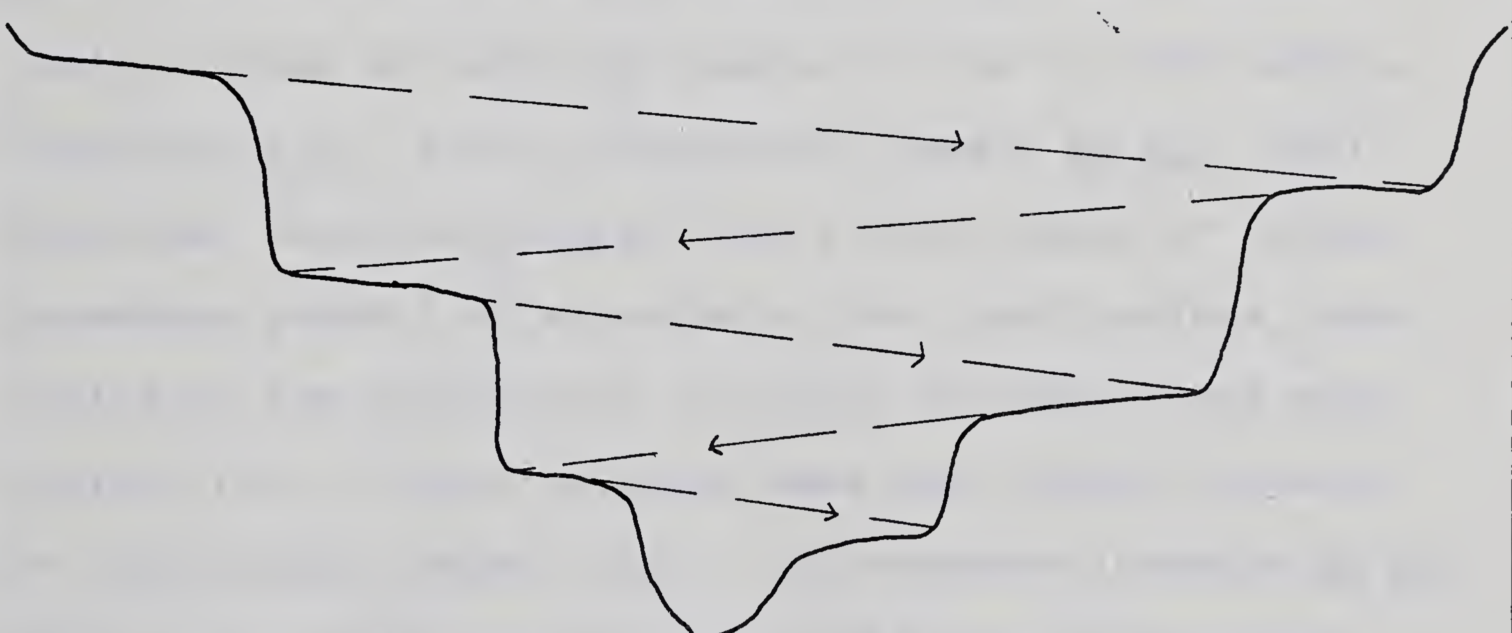

Figure 2:4 Non-Cyclic Terraces

ment of its channel (Mackin, 1948) and leave terraces of unequal altitude on opposite sides of the stream. These terraces are called non-cyclic (Cotton, 1940) or unpaired terraces (Frye and Leonard, 1954; Leopold _et al_, 1964). Non-cyclic terraces usually reflect slow continual tectonic uplift or isostatic rebound. Both these processes have been minimal or non-existent in the Weed Creek basin and such non-cyclic terraces are rare. Fig. 2:4 depicts some non-cyclic terrace features.

Erosional and Depositional Terraces. These terraces may be either cyclic or non-cyclic but are differentiated by their internal structure. Erosional terraces are formed mainly when a river meanders from one side of its floodplain to the other eroding laterally into the bedrock valley slopes or into the remains of one or more earlier deposits (e.g., till) or alluvium (Howard _et al_, 1968). Erosional terraces usually have a thin veneer of contemporaneous gravels or alluvium on the tread surface indicative of the differences in cycles to that of the main terrace fill. These terraces have been called terraces of destruction (Magee, 1891), cut terraces (Leopold _et al_, 1964), scour terraces (Gooding, 1957), or just eroded terraces (Zeigler, 1958)(Fig. 2:5).

The depositional terraces are formed mainly in excavations of valley fill or alluvium previously deposited by the stream. Alluviation in any one gross cycle is

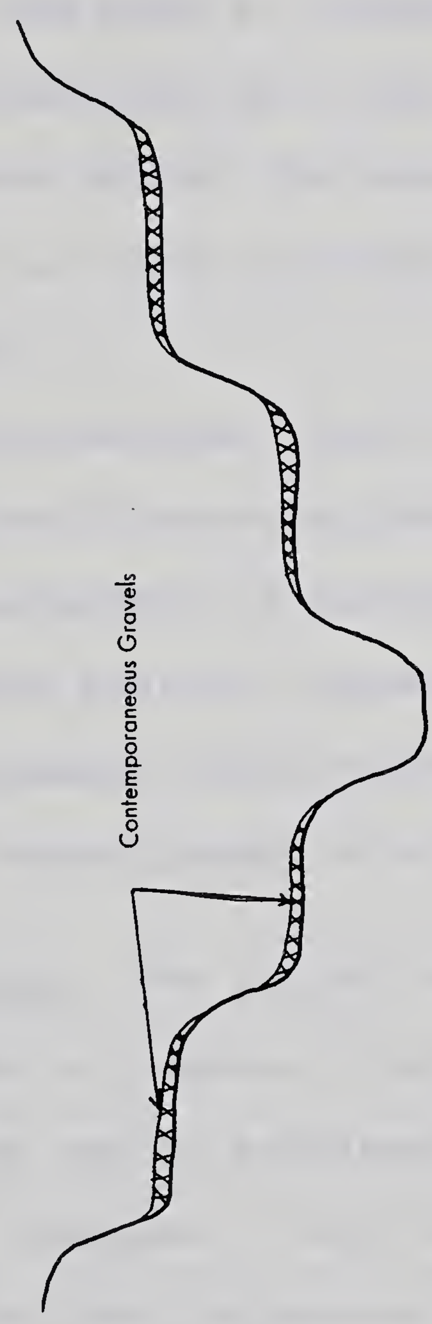

Figure 2:5 Erosional Terraces

likely to pass through a coarse, medium and fine gradation from bottom to top; in detail, the valley fill may include many small lenses, each cross-bedded from bottom to top as in the case of either a meandering stream or a braided stream or in the case of overbank discharge parallel bedding may appear (Howard et al, 1968). These depositional terraces have been called 'terraces of construction' (Magee, 1891, p. 256) or 'fill terraces' (Leopold et al, 1964; Zeigler, 1958).

Though erosional terraces can either be cyclic or non-cyclic, the alternating succession of aggradation and degradation processes in the North Saskatchewan River valley suggests that its terraces and those of its tributaries are probably depositional in nature. Fig. 2:3 shows an idealized stratigraphy of a depositional terrace.

Terrace Geology. The geology of terraces usually indicates the kind of process involved in their formation. Two such types are of pertinence: (a) Rock terraces, and (b) Alluvial terraces. Rock terraces are mainly of the erosional type, cut in bedrock and usually veneered with a layer of former flood-plain alluvium (Thornbury, 1969). These features are sometimes called 'strath' terraces (Cotton, 1940).

Alluvial terraces are formed completely of river alluvium or some other fill (e.g., till). These terraces are most common but less likely to be preserved due to

their low resistance to erosion. A special kind of alluvial terrace is the 'rock defended terrace'. Usually a layer of alluvium is preserved from erosion by the resistance of the underlying bedrock to stream action. The bedrock unit may or may not have been previously cut, shaped or eroded by the stream. The Weed Creek terraces appear to be of the alluvial type.

Correlation of River Terraces

In appraising the correlation of stream terraces, the height and continuity distribution along the river should be considered (Leopold et al, 1964). In addition, the genesis and geologic structure of the terraces are of vital importance. If there has been a history of alternating fluvial aggradation and degradation, such as has been proposed for the North Saskatchewan River valley and its tributaries (Rains, 1969; Westgate, 1969), terraces should develop at different levels. If there are only one or two levels with widely spaced intervals, and with the continuity of each level well preserved, then the separation between levels would not be difficult. In such a situation, the geometry of height and continuity may serve as a very reliable measure for correlation. But few such straight-forward and simple cases exist. The vertical interval between several terrace levels may be small thus causing a less permissible height variation for each

level. Also the preservation of terraces may be poor causing difficulties in determining the continuity pattern. Because of such problems, correlation based on height and continuity alone may sometimes be unreliable. Frye and Leonard (1954) have shown by examples in the Smoky Hill river, Kansas, how colluvium and pediments can create false terraces or mask existing ones whose presence can, in most cases, only be determined by their stratigraphy. Gooding (1957) considers the internal geologic structure of terraces as one of the criteria for differentiating terrace types. He indicates the importance of differentiating between types of terraces, i.e., erosional and depositional, when attempting to relate them to the climatic and geomorphic history of a region. Ideally, a geologic sequence and genesis is also needed for terrace correlation.

The base-level control of the Weed Creek terraces suggests that they may be of cyclic origin divided into perhaps two or three different levels. If so, there will be a tendency for heights to group around their respective mean levels with a scarcity of heights grouping around the midpoints between the means. The existence of such a pattern would provide a satisfactory statistical basis for correlation by height. Bedrock and terrace heights may be suitably grouped but dispersion and graphic techniques may not provide adequate separation.

Correlation of terrace levels may be adequate if restricted to the particular study basin, but the interrelationship of terraces between the study basin and other basins in the same watershed could provide an added and reliable dimension for building a sound correlation. Such a condition exists between the Weed Creek basin and the Whitemud and North Saskatchewan River valley, near Edmonton. A positive method of correlating terraces in two or more different valleys is to trace them until they merge at a valley junction or join a similar terrace in a trunk valley to which the valleys are tributary (Thornbury, 1969). This method, however, is not the only one suitable for multiple-valley terrace correlation. If cyclic terraces of two or more stream basins within a region are formed, there is no prima-facie evidence that similar terrace heights and profiles will exist between the basins. Also, the stream basins may not all be of similar size. But as Culling (1957) points out, cyclic formed terraces usually have longitudinal profiles which are roughly parallel each to its own present stream and have an even thickness of alluvial deposits on bedrock though possibly different from valley to valley. This being the case, there should exist an equal number of terrace levels within each valley and these terrace levels should bear an equal height-percentage[1] relationship to the maximum incision

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[1]Height-percentage is the percentage height of a terrace or terrace level to that of the maximum valley depth.

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depth of its respective valley. Paired terraces within one valley will group around its respective means whereas paired terraces within several adjacent basins will group around their respective height-percentage means for each terrace level within the region. Though the mean height of a particular terrace level within one basin may be different from that of another or other basins, irrespective of size, the terrace levels height-percentage means of all the basins should bear a close similarity.

Causes for Differences in Terrace Heights of a Particular Level

Many writers have referred to correlated terrace levels as the 10, 20, or 30 foot terrace level. This nomenclature causes problems because terraces of any terrace level usually vary in height above the present channel (Howard, 1959), and nature rarely fashions terraces or other forms with such precision(Johnson, 1944). Terrace levels should each have a particular height range where terraces falling into that height range could be designated to that particular level. Height variations within a particular terrace level are the rule and not the exception. Such variations are due to minor changes in the equilibrium conditions of the stream system where a change in one of the hydraulic factors causes a response in the others in order to acquire a new equilibrium state. At

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least seven conditions cause variations in terrace height of a particular terrace level. They are as follows:

(1) Meander cut off - which causes an increase in stream gradient in that section of the stream resulting in degradation. A graphic representation is shown in Fig. 2:6.

(2) A depositional terrace that is partly eroded in sections (called 'ledges' by W.M. Davis, 1902). Davis states that "the frequent swinging of the meander belt from side to side during the slow degradation of the valley floor requires that the discovery of every 'ledge' lying well within the belt of wandering should be made soon after the stream has degraded the valley floor to the level of the ledge top." (Fig. 2:7)

(3) Knickpoint recession (Culling, 1957). A graphic representation serves as an adequate explanation. (Fig. 2:8)

(4) Height differences between the cut bank terrace and slip-off slope terrace (Cotton, 1948). Fig. 2:9 is self-explanatory.

(5) Effects of tributary entrance to the trunk stream through alluvial fan deposits.

(6) Overlapping of terrace levels where floods from the former lower terrace level stream inundates sections of the immediately higher level terrace.

(7) Differences in gradients of terrace and present stream longitudinal profiles which are not always parallel because of local variances in bedrock resistance (Frye and Leonard, 1954). See Fig. 2: 10.

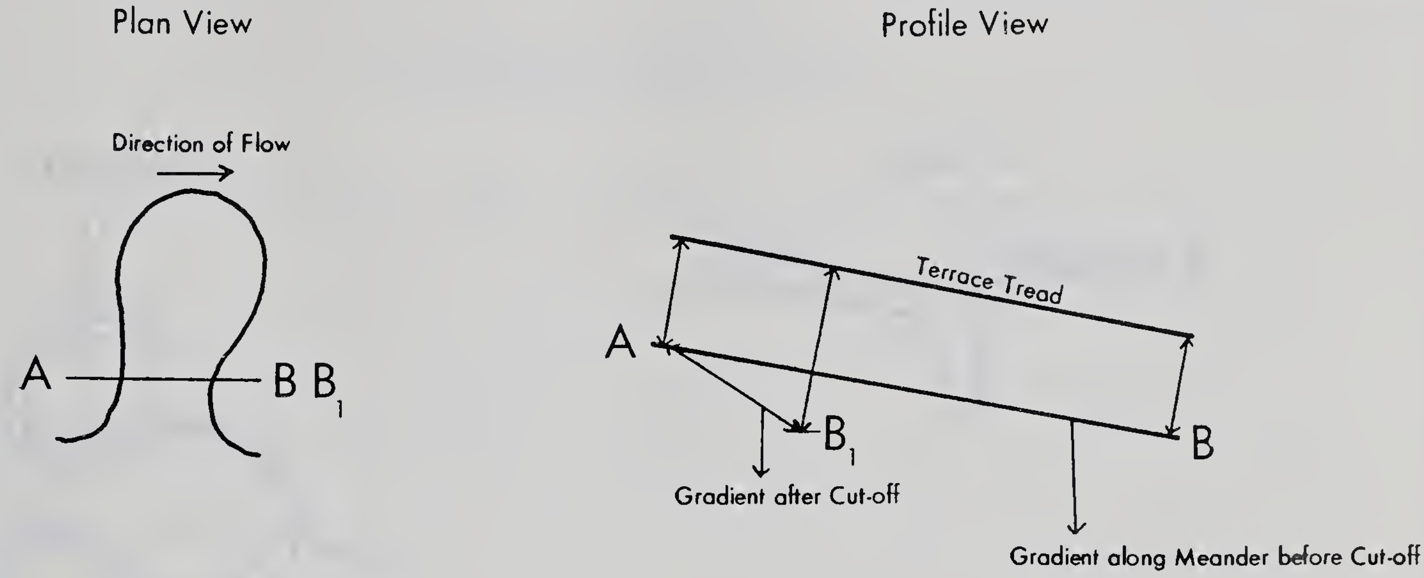

Figure 2:6. Meander Cutoff

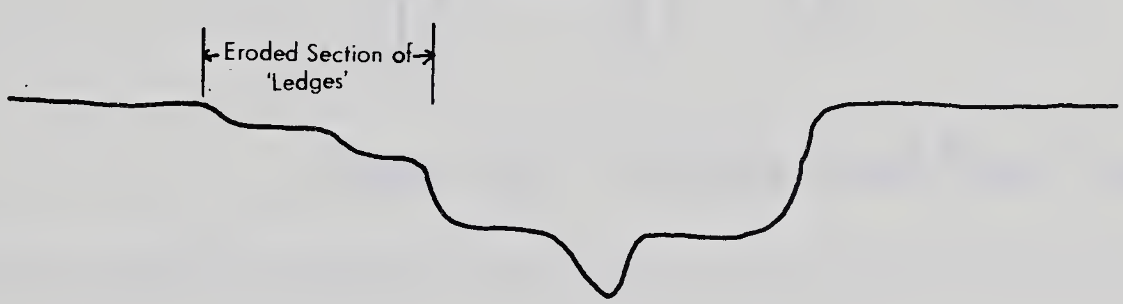

Figure 2:7 Partially Eroded Terrace

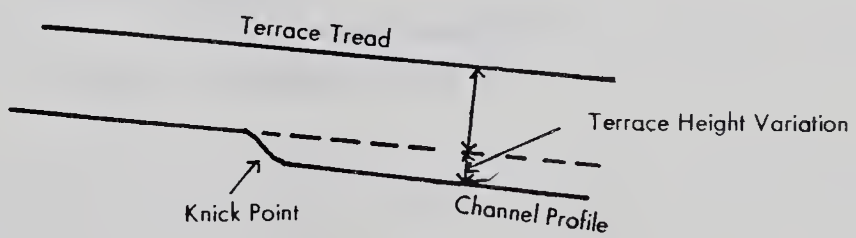

Figure 2:8 Knick Point Recession

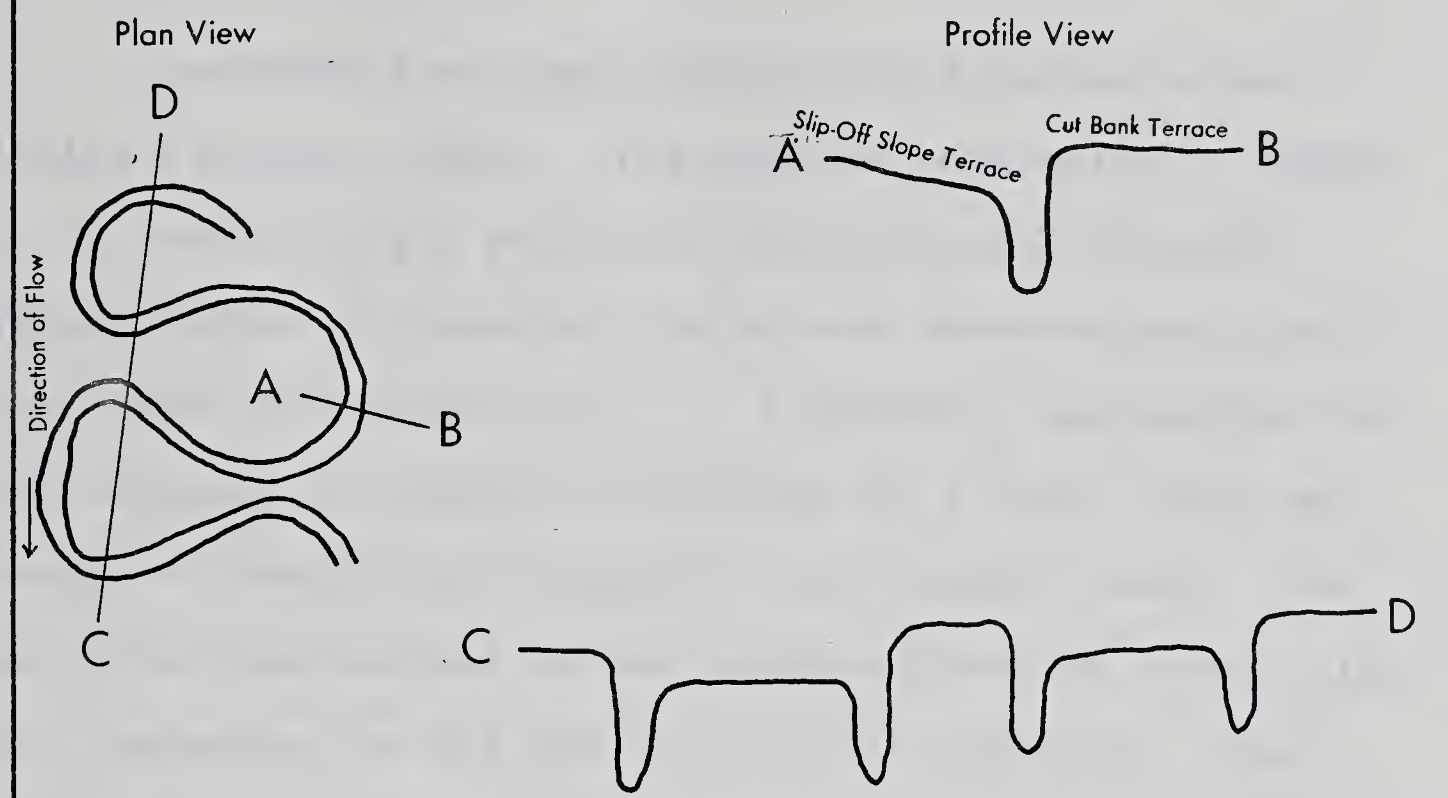

Figure 2:9 Cut Bank Slipoff Slope Terrace

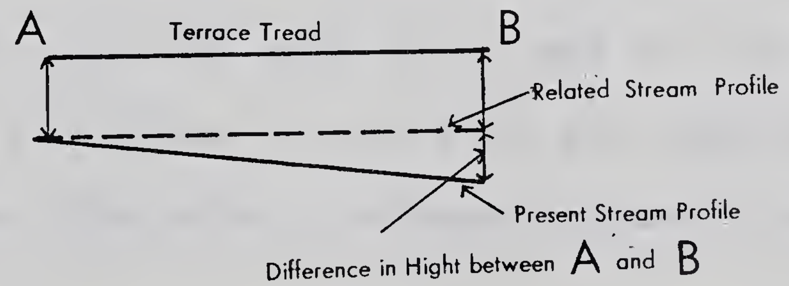

Figure 2:10 Effect of Local Gradient Variation

Terrace Continuity

Terraces are rarely equally distributed along a valley (Johnson, 1944). The premise continuity is based on is that during a period of relative stability, the stream formed a floodplain which was more-or-less continuous along the valley (q.v.). Succeeding degradation and the building of another floodplain at a lower level may partly or completely eliminate and original level. The degree of destruction of the terrace level or levels will vary depending on the age and type of terraces. Thus, terrace remnants may be fairly continuous along the valley, as is usually the case for young or recently formed terraces, or may remain only as isolated patches as is expected for older terraces. Furthermore, the probability of older higher terraces being preserved is less than the younger lower terraces simply because of the greater age of the higher terraces. Terraces may appear on both sides of the valley opposing each other and at the same height, or may occur sometimes on one side and sometimes on the other but each displaced upstream or downstream from one another.

If only one or two terrace levels exist, correlation by continuity may not be difficult but where many levels exist, then the continuity of levels becomes difficult to unravel without some knowledge of their geology. Continuity patterns are usually displayed in planimetric or

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profile views or both.

Terrace Heights

The problem of determining height levels lies in deciding from which datum to measure the terrace elevations. The existing floodplain may provide a reasonable base for measuring terrace heights where it is a relatively level and continuous surface. However, the floodplain will not always be present along every section of the stream making terrace height measurements difficult. In small watersheds, as in basins where the terrace intervals are of a short time duration, it may be difficult to distinguish between the floodplain and the lower terrace level (Leopold <u>et al</u>, 1964). The water surface level of the present stream, because of its continuous nature, provides a very reliable datum from which to measure terrace heights; times of measurement should avoid flood and high water stages. Floodplain and terrace heights both appear to bear a relatively constant relationship to former terrace levels (Johnson, 1944) and whether or not the present stream profile is parallel to the previous level profile or profiles, it is a continuous surface from which measurements can be taken and rechecked.

It is important in terrace height measurement to determine what section of the terrace to measure. The terrace edge--tread front--is not always suitable, since

it may be eroded, and the rear of the terrace tread may be covered with colluvium (Frye and Leonard, 1954). The most reliable surfaces to measure are the former related bedrock-cut and channel-gravel surfaces along the present stream channel. Where these are not visible or exposed, then the terrace tread fronts can be used (Johnson, 1944). The presence of relatively constant thicknesses of alluvial deposits of the terraces will strengthen such a choice.

There are instances when the longitudinal terrace profiles differ drastically from each other and the present stream. In such a case, the former stream profiles of the related terrace levels should be reconstructed if possible. Leopold (et al, 1964) suggests that if the terraces are in pairs, i.e., remnants on each side of the valley, planes on each are projected to an intersection. When the plane of a single terrace intersects the far side of the valley, or where the two planes from opposite sides intersect, is considered the lowest elevation at which the river could have been flowing when it formed the floodplain that later became the terrace surface. This method of reconstructing previous profiles can be supplemented by considering old meander channel scars, bedrock and stream gravel heights. If previous profiles are reconstructed, then the basis for correlation is strengthened and terrace heights can be related not only to the present stream level but also to previous stream levels.

Once terraces have been classified by cause, mode of formation and geologic structure, then terrace correlation can be further established by continuity and height analysis. Only then should a chronology be suggested. Correlation and chronology assist in the unraveling of the geomorphic history of the region concerned.

CHAPTER III

DESCRIPTION AND ANALYSIS OF THE WEED CREEK TERRACES

The description and analysis of the Weed Creek terraces are drawn from investigation of their longitudinal distribution along the present stream profile, planimetric distribution and mapping, and several cross-valley profiles. The investigation and reconstruction of the longitudinal terrace distribution included plots of the terrace tread heights above their adjacent water levels and bedrock or gravel heights wherever these were exposed above their adjacent water levels. The planimetric distribution and mapping of their terraces were compiled from stereoscopic interpretation of aerial photographs and field investigation of the longitudinal terrace height distribution. Complete planimetric field checking was not attempted due to the presence of the thick forest understory in some of those areas not cleared for pasture or agriculture. The cross-valley profiles show the horizontal and lateral attitude of many of the terraces. Simple statistical tests have been used in differentiating the terrace levels in the Weed Creek basin and in comparing them with those of Whitemud basin and the North Saskatchewan in the Edmonton area.

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Grouping and Differentiation of the Terrace Levels

The general longitudinal stream profile of the Weed Creek basin is convex upwards with some sections showing a concavity. The concave sections are found mainly below knick-points (Fig. 3:1). Dispersion diagrams of the bedrock, gravel and terrace heights, as measured along the stream channel from its mouth to Thorsby (Fig. 3:2), were made and studied, but no evident pattern of grouping was discernible. There are four probable reasons for this: first, either the bedrock-gravel surfaces and the terraces are non-cyclic; or second, the varying differences in depth of the valley between its mouth and Thorsby has masked the pattern; or third, a combination of the above two reasons; or fourth, the range of amplitude between the terraces is too small to show using this particular technique.

The problem is whether the terraces with their bedrock and gravel heights are of cyclic or non-cyclic origin. The proposed hypothesis will be that they are cyclic. The bedrock heights between cross-valley profiles 4 to 8 (Figs. 3:1 and 3:2) were then grouped. This was done since the valley depth between these cross-valley profiles is fairly constant (Fig. 3:1).[1]

The data is presented in the form of a histogram

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[1]The bedrock heights were first converted to percentage heights in order to minimize the effects of valley depth variations.

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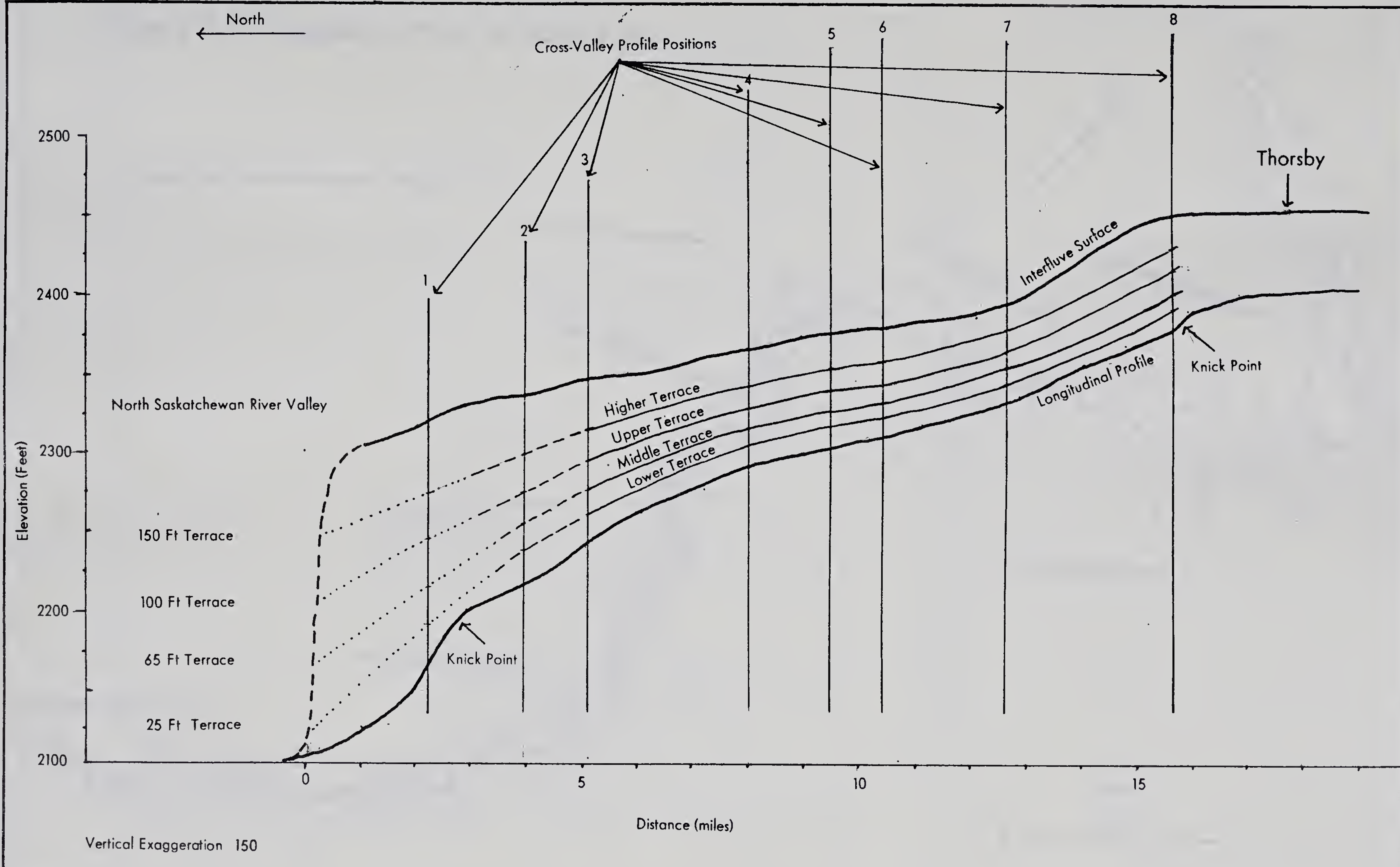
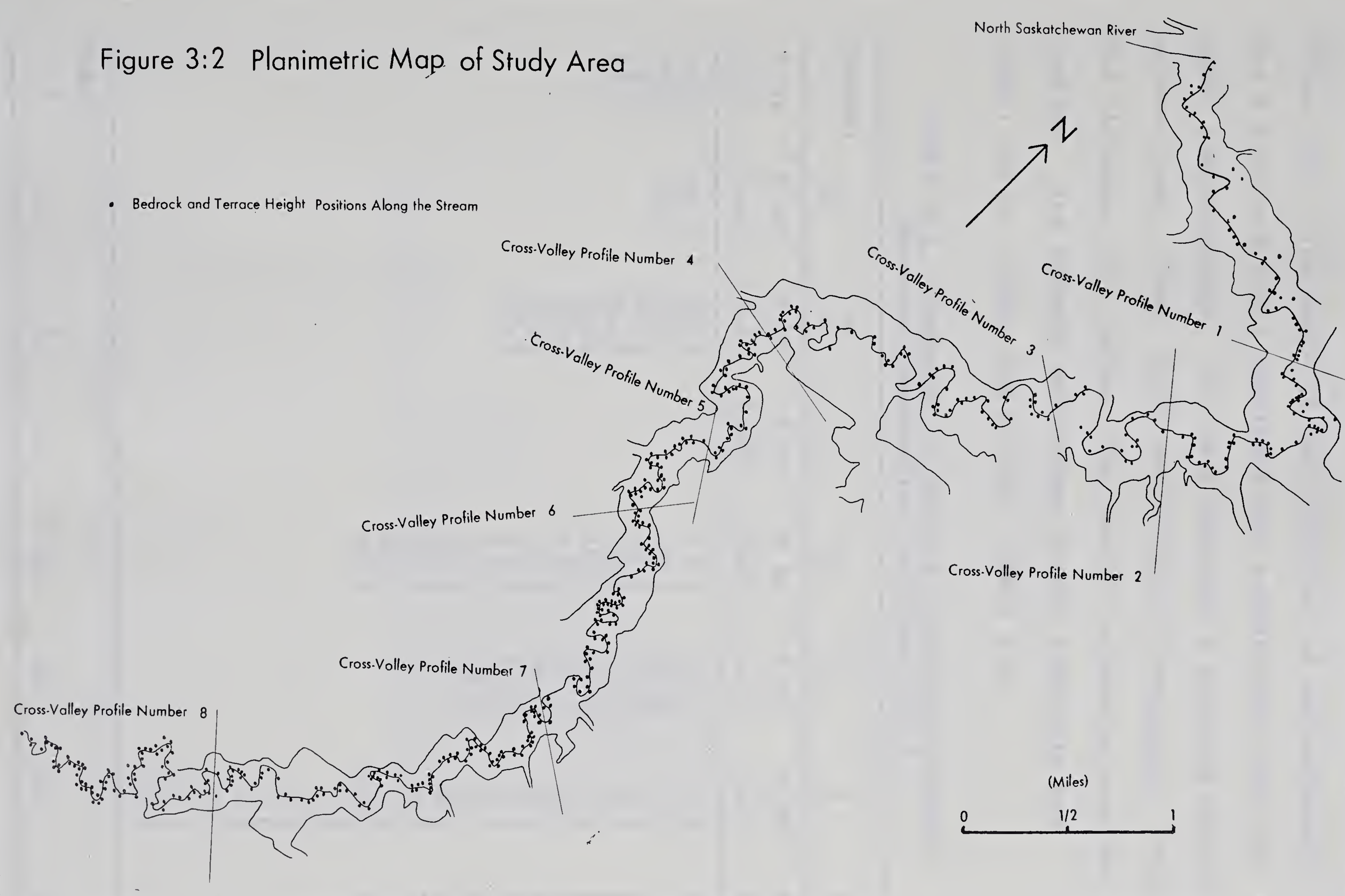


Figure 3:1 Weed Creek Terrace Elevations

Figure 3:2 Planimetric Map of Study Area



(Fig. 3:3). The range of each interval is approximately 7. The 6.5-13 and 0-6.5 intervals are sub-divided into two equal sub-intervals. The data displays a grouping pattern in the 41-48, 27-34, 13-20 and 3.25-9.75 intervals. Using the histogram as a guide, four bedrock intervals were delimited. The bedrock percentage height intervals are 45-52, 26-36, 17-22, and 2.5-10. (Table 3:1)

TABLE 3:1. Grouping of Bedrock Percentage-Heights Between Cross-Valley Profiles 4 to 8

Groups: 1	2	3	4	5	6	7	8
% Ht 45-52	% Ht 37-45	% Ht 27-37	% Ht 22-27	% Ht 17-22	% Ht 12-17	% Ht 5-12	%Ht 0-5
45.0	39.5	33.2	-	17.5	15.1	7.0	4.0
45.9	41.2	28.7		18.3	12.0	5.0	3.0
49.8		27.0		16.8	14.0	9.7	4.0
51.1		28.0		19.8	11.8	7.0	3.0
		31.0		18.6	14.5	7.2	3.0
		29.8		17.5	14.1	6.0	3.5
		26.6		19.9	14.3	8.0	4.0
		28.5		17.2	11.5	9.5	4.0
				17.5	12.3	5.5	2.5
				21.1	14.6	6.0	4.0
				22.6		8.6	4.5
				22.4		5.0	2.5
				21.9		8.0	3.5
				16.8		10.0	4.0
						8.0	
						8.0	
						9.1	
						5.0	
						5.0	
						6.0	
						11.0	
						11.0	
						10.6	
Totals: 4	2	8	-	14	10	23	14

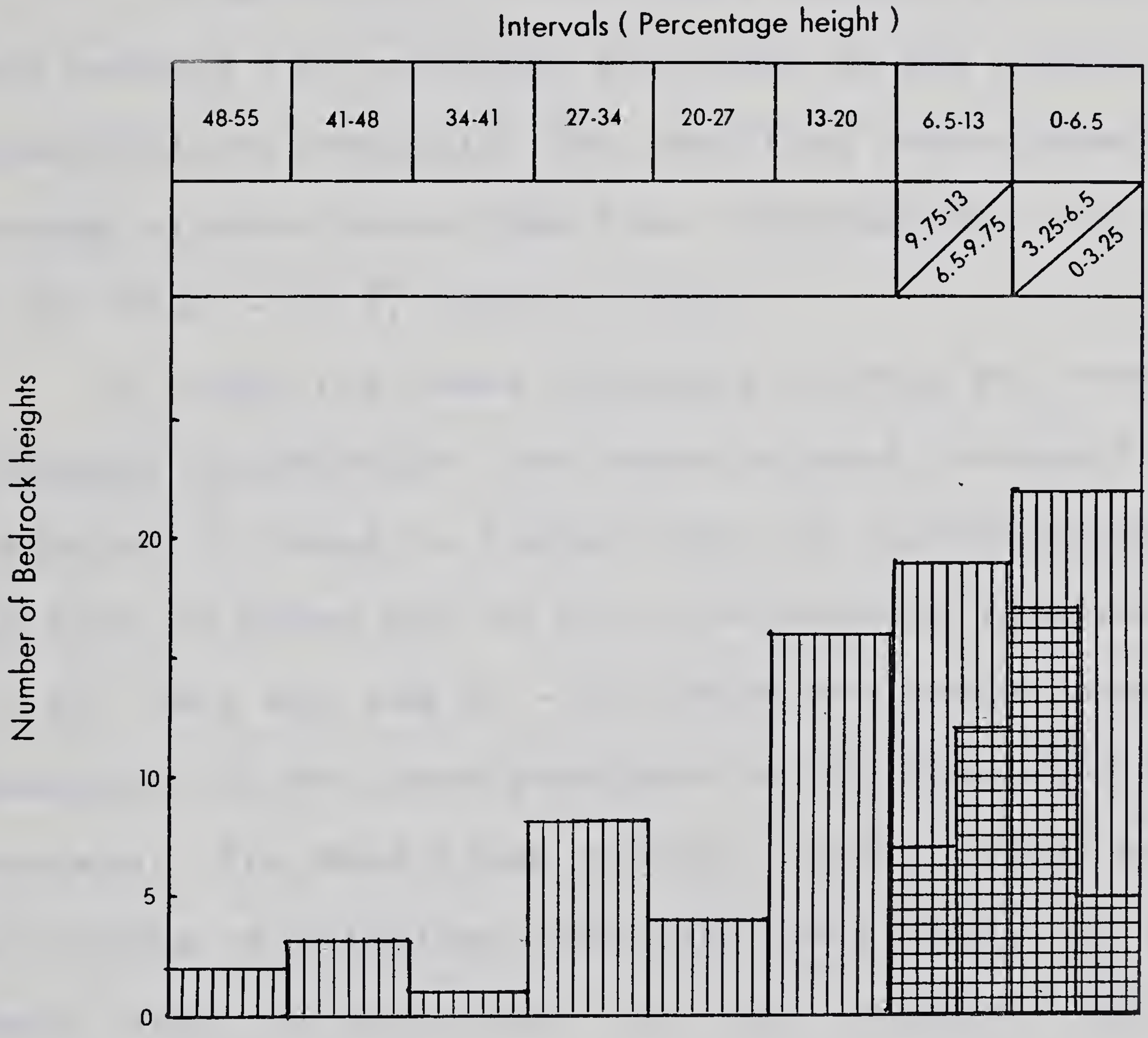


Figure 3:3 Histogram of Bedrock Percentage Heights

The average thicknesses of alluvial deposits related with each bedrock interval were then calculated.[2] The average thickness of the alluvial deposits are 7.4 feet, 6.7 feet, 6.3 feet and 6.3 feet for the bedrock percentage height intervals 45 - 52, 27 - 37, 17 - 22 and 2.5 - 10, respectively. When these average alluvial deposit heights are converted and added to the bedrock percentage-height intervals, the resulting percentage-height terraces cluster around the four intervals 68 - 77.3, 44- 56, 30.7 - 37.3, and 11 - 21.3.

In order for these intervals to have any meaning in terrace correlation, the non-clustered intervals should be similar in range or larger than the clustered intervals. This fact is borne out in the non-clustered intervals of 57 - 67, 38 - 43, and 22 - 30, where the ranges are approximately of the same magnitude as the clustered terrace intervals. The Weed Creek terraces tend to group around four levels as delimited above and for purposes of this thesis, shall be designated the lower, middle, upper and higher terrace levels.

For the mean thicknesses of the alluvial deposits to be representative, their standard deviation should be small. The means and their standard deviations are presented in Table 3:2. The standard deviation is indeed

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[2]The individual thicknesses of alluvial deposits above exposed bedrock sections along the stream channel from its mouth to Thorsby were used in the calculation.

small, where for each interval except the higher, it is less than 3; the higher interval is just above 3 at 3.109.

TABLE 3:2. Mean and Standard Deviation of the Terrace Alluvial Deposits

Terrace Level	Mean (Feet)	Standard Deviation (S.D.)	Number of Unit Heights
Lower	6.28	2.184	46
Middle	6.31	2.218	29
Upper	6.73	2.659	15
Higher	7.41	3.109	-

The terrace levels were then compared with those of the Whitemud basin. A section of comparable dimension to the Weed Creek basin, between cross-valley profiles 4 to 8, was chosen (Fig. 3:4). Percentage-height intervals for the Whitemud terraces were calculated at mile 10, 12, 13, 15, 17, 18 and 20 above the Blackmud and Whitemud confluence. The intervals for the higher, upper, middle and lower terraces, as calculated, are 66 - 73, 45 - 57, 30 - 38 and 13 - 22, respectively. The close similarities of the intervals to those of the Weed Creek basin are very evident (Table 3:3).

TABLE 3:3. Comparison of the Weed Creek and Whitemud Creek Terrace Percentage Heights

Basins	Levels			
	Lower	Middle	Upper	Higher
Weed Creek	11 - 21	31 - 37	44 - 56	68 - 73
Whitemud	13 - 22	30 - 38	45 - 57	68 - 73

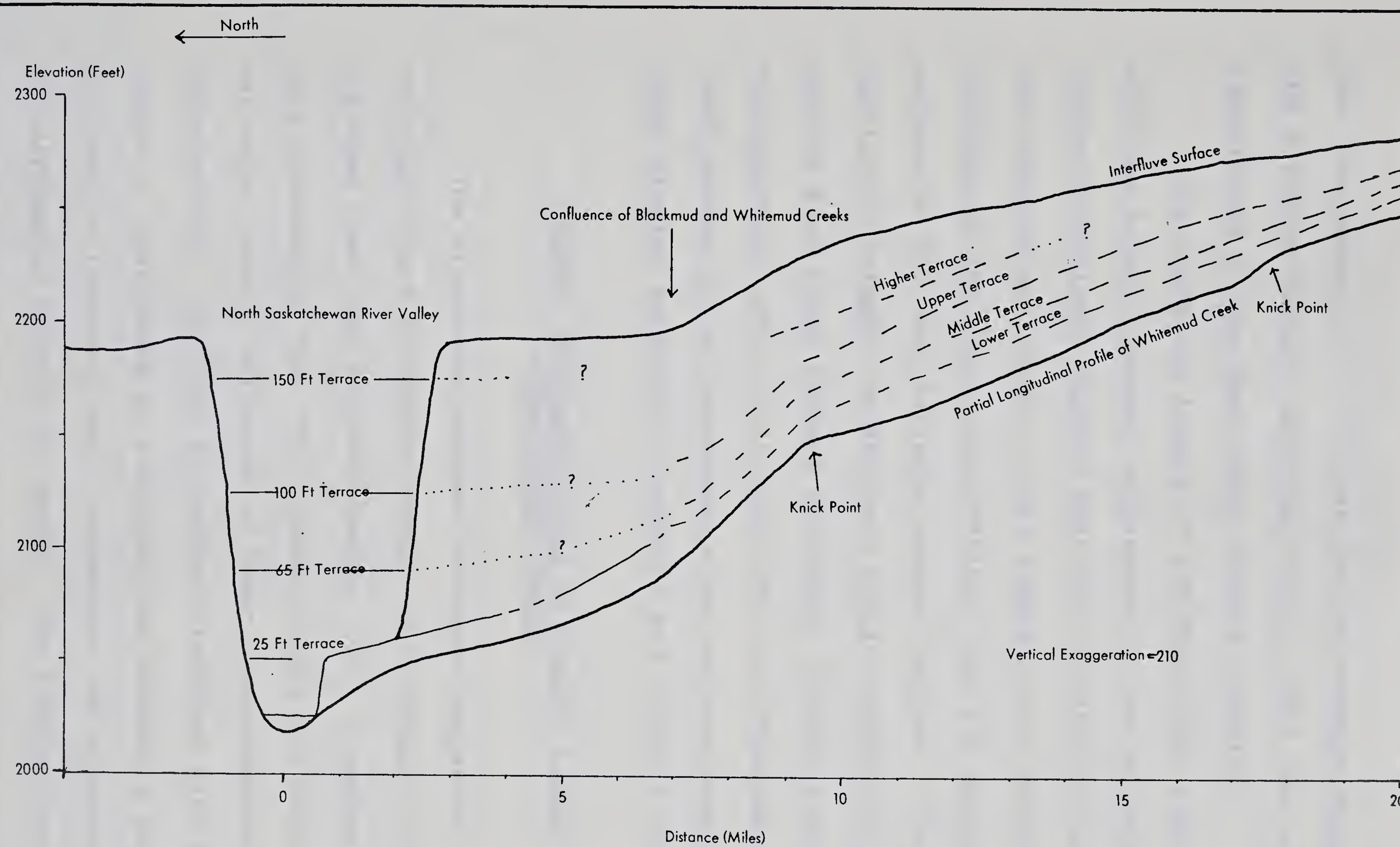

Figure 3:4 North Saskatchewan River and Whitemud Creek Terrace Elevations

(Modified from Rains, 1969)

Even the range of 5 - 10 feet for the average thickness of the Whitemud terrace deposits (Rains, 1969) bear similar proportions to the Weed Creek terrace deposits.

The clustered levels of the Weed Creek basin, along with the fairly constant thicknesses of the alluvial deposits tentatively suggest that the correlating pattern of the terraces are cyclic. This suggestion is strengthened considering the levels were derived from the dispersion pattern of the very reliable bedrock heights. The close similarity between the Whitemud cyclic terrace intervals and the Weed Creek terrace intervals, further strengthen the suggestion when it is noted that the Whitemud and Weed Creek basins are of comparable size and have developed under similar geomorphic, geologic and climatic conditions.

Further Differentiation of Terrace Levels --Statistical Tests

The dispersion diagram procedure suggested a probable non-significant difference between the terrace levels of the Weed Creek and Whitemud basins, i.e., a suggestion of good probability that the terraces of the two basins are not significantly different in their percentage-height relationship. This can be further clarified with a higher degree of confidence by employing the Student-t test. It provides an Index--t, which represents the relationship of the difference between two means. The Index--t can then be referred to prepared tables or a graph from which the

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degree of significance of the difference can be assessed (Gregory, 1971). If the Student-t exceeds the value derived from the prepared tables or graph, then the means and the samples they represent are significantly different; if the Student-t falls below the value--null hypothesis--it does not conclusively prove a similarity between the means but suggests a high degree of probability that the means and their samples are not significantly different. The 'mean' $\left(\bar{x} = \frac{\sum_{i}^{n} x}{n}\right)$, 'standard deviation' $\left(\text{S.D.}\ \sigma = \sqrt{\frac{\sum(x-\bar{x})^2}{n}}\right)$ and the 'best estimate' of the S.D. $\left(\hat{\sigma} = \sigma\sqrt{\frac{n}{n-1}}\right)$ were then calculated for each terrace level in both the Weed Creek and Whitemud basins (Table 3:4).

Eight cross-valley profiles were also produced at varying intervals along the valley (Fig. 3:1 and 3:2). Terrace tread percentage heights were delimited for the section between cross-valley profiles 4 to 8, were grouped on the basis of the levels designated and used in the statistical tests.

A Student-t test was then calculated to compare the differences between the means of the related levels. The Student-t is expressed by the equation:

$$t = \frac{|\bar{a} - \bar{b}|}{\sqrt{\frac{\hat{\sigma}_a^2}{n_a} + \frac{\hat{\sigma}_b^2}{n_b}}} \qquad (1)$$

where t is the Student-t, a and b are the means of each sample in each level, and n_a and n_b are the respective sample sizes.

Table 3:4. Mean, Standard Deviation, Best Estimate of Standard Deviation -- Weed Creek and Whitemud Creek Terraces

	Levels	Mean	Standard Deviation	Best Estimate of Standard Deviation	vs Mean	Standard Deviation	Best Estimate of Standard Deviation
1. WTD vs. WK X-VAL	Higher	68.9	2.708	3.028	69.0	7.091	7.437
	Upper	52.4	4.167	4.370	50.1	4.853	5.024
	Middle	32.8	2.521	2.645	32.2	5.442	5.583
	Lower	18.2	2.563	2.688	17.2	4.105	4.224
2. WTD vs. WK X-VAL (R.S.)	Higher	68.9	2.708	3.028	69.6	6.032	6.965
	Upper	52.4	4,167	4.370	51.3	5.770	6.663
	Middle	32.8	2.521	2.645	31.7	5.474	5.741
	Lower	18.2	2.563	2.688	18.3	4.890	4.159
3. WTD vs. WK X-VAL (L.S.)	Higher	68.9	2.708	3.028	68.7	8.076	8.723
	Upper	52.4	4.167	4.370	49.7	4.717	4.947
	Middle	32.8	2.521	2.645	32.9	5.657	6.000
	Lower	18.2	2.563	2.688	16.9	4.486	4.705
4. WK X-VAL (L.S.) vs. WK X-VAL (R.S.)	Higher	68.7	8.076	8.723	69.6	6.032	6.956
	Upper	49.7	4.717	4.947	51.3	5.770	6.663
	Middle	32.9	5,657	6.000	31.7	5.474	5.741
	Lower	16.9	4.486	4.705	18.3	3.890	4.159
5. WTD vs. WK (67)**	Higher	68.9	2.708	3.028	75.4	8.602	9.617
	Upper	52.4	4.167	4.370	48.9	6.043	6.271
	Middle	32.8	2.521	2.645	31.6	4.629	4.707
	Lower	18.2	2.563	2.688	13.6	6.259	6.306
6. WK (51)*** vs. WTD	Higher	68.9	2.708	3.028	75.4	8.602	9.617
	Upper	52.4	4.167	4.370	48.9	6.043	6.271
	Middle	32.8	2.521	2.645	31.6	4.629	4.707
	Lower	18.2	2.563	2.688	16.1	4.829	4.877
7. WK (67) vs. WK X-VAL (L.S.)	Higher	68.7	9.076	8.723	75.4	8.902	9.617
	Upper	49.7	4.717	4.947	48.9	6.043	6.271
	Middle	32.9	5.657	6.000	31.6	4.629	4.707
	Lower	16.9	4.486	4.705	13.6	6.259	6.306
8. WK (51) vs. WK X-VAL (L.S.)	Higher	68.7	8.076	8.723	75.4	8.602	9.617
	Upper	49.7	4.717	4.947	48.9	6.043	6.271
	Middle	32.9	5.657	6.000	31.6	4.629	4.707
	Lower	16.9	4.486	4.705	16.1	4.829	4.877
9. WK (67) vs. WK X-VAL (R.S.)	Higher	69.6	6.032	6.965	75.4	8.602	9.617
	Upper	51.3	5.770	6.663	48.9	6.043	6.271
	Middle	31.7	5.474	5.741	31.6	4.629	4.707
	Lower	18.3	4.890	4.159	13.6	6.259	6.306
10. WK (51) vs. WK X-VAL (R.S.)	Higher	69.6	6.032	6.965	75.4	8.602	9.617
	Upper	51.3	5.770	6.663	48.9	6.043	6.271
	Middle	31.7	5.474	5.741	31.6	4.629	4.707
	Lower	18.3	4.890	4.159	13.6	6.259	6.306
11. WK (51, L.S.) vs. WK X-VAL (L.S.)	Higher	-	-	-	-	-	-
	Upper	49.7	4.717	4.947	47.0	5.703	6.097
	Middle	32.9	5.657	6.000	32.0	4.740	4.886
	Lower	16.9	4.486	4.705	17.2	4.327	4.413
12. WK (51, R.S.) vs. WK X-VAL (L.S.)	Higher	-	-	-	-	-	-
	Upper	49.7	4.717	4.947	51.4	5.976	6.546
	Middle	32.9	5.657	6.000	31.2	4.624	4.813
	Lower	16.9	4.486	4.705	16.2	4.149	4.264
13. WK (51, R.S.) vs. WK X-VAL (R.S.)	Higher	69.6	6.032	6.965	-	-	-
	Upper	51.3	5.770	6.663	51.4	5.976	6.546
	Middle	31.7	5.474	5.741	31.2	4.624	4.813
	Lower	18.3	4.890	4.159	16.2	4.149	4.264
14. WK (51, L.S.) vs. WK X-VAL (R.S.)	Higher	69.6	6.032	6.965	-	-	-
	Upper	51.3	5.770	6.663	47.0	5.703	6.097
	Middle	31.7	5.474	5.741	32.0	4.740	4.886
	Lower	18.3	4.890	4.159	17.2	4.327	4.413
15. WK (51, L.S.) vs. WK (51, R.S.)	Higher	68.7	8.076	8.723	-	-	-
	Upper	49.7	4.717	4.947	51.4	5.976	6.546
	Middle	32.9	5.657	6.000	31.2	4.624	4.813
	Lower	16.9	4.486	4.705	16.2	4.149	4.264

* WTD - WHITEMUD TERRACES
WK - WEED CREEK TERRACES
X-VAL - CROSS-VALLEY PROFILE TERRACES
B.S. - BOTH SIDES
R.S. - RIGHT SIDE
L.S. - LEFT SIDE

** All Terrace Measurements
*** All Terrace Measurements Except Those Less Than 9% of Valley Depth

The calculated Student-t values were made for the comparisons of the Weed Creek mean terrace heights and also the Weed Creek cross-valley profile mean terrace heights. The significance or non-significance of the values are presented in Table 3:5.

For all the comparisons (Table 3:5), the null hypothesis was accepted, i.e., the means compared were not significantly different, with the lower level means between the Whitemud terraces and the Weed Creek terraces (67)(No. 5--Table 3:5) and the lower level means between Weed Creek terraces (67) and the Weed Creek cross-valley profile terraces (right side)(No. 9--Table 3:5) being the exceptions.

The significant difference between the lower level means--Table 3:5, Nos. 5 and 9--can be explained. The Weed Creek terraces (51) are identical to the Weed Creek terraces (67) with the exception of terraces less than 9 percent of the full valley depth. The terrace heights less than 9 pecent are all situated in that part of the stream between the mouth and cross-valley profile No. 4 (Figs. 3:1 and 3:2). In this section of the stream, the longitudinal gradient is considerably steeper than the rest of the profile. This is probably due to either rejuvenation taking place or a higher rate of downcutting caused by a difference in the geology of the basin; remember this is the section of the stream that is coinciden-

Table 3:5. Student-t Test on Terraces of the Weed Creek and Whitemud Creek Basins

No.	Comparisons Between Terraces*	Student-t Values				Tabled Student-t at 10% Probability Level ($t_{.01}$)				Degree of Freedom				Significant Difference			
		Higher	Upper	Middle	Lower	Higher	Upper	Middle	Lower	Higher	Upper	Middle	Lower	Higher	Upper	Middle	Lower
1.	WTD vs. WK X-VAL (R.S.)	0.0706	1.2649	0.3759	0.8144	1.345	1.318	1.311	1.314	14	24	29	27	No	No	No	No
2.	WTD vs. WK X-VAL (R.S.)	0.2048	0.3267	0.5724	0.0325	1.415	1.350	1.325	1.333	7	13	20	17	No	No	No	No
3.	WTD vs. WK X-VAL (L.S.)	0.0529	1.3886	0.0446	0.8179	1.372	1.775	1.330	1.325	10	20	18	20	No	No	No	No
4.	WK X-VAL (L.S.) vs WK X-VAL (R.S.)	0.1988	0.4365	0.4487	0.6808	1.383	1.350	1.330	1.333	9	13	18	17	No	No	No	No
5.	WTD vs. WK (67)**	1.4416	1.6731	0.9769	4.1914	1.860	1.714	1.282	2.576	8	23	39	76	No	No	No	Yes
6.	WK (51)*** vs. WTD	1.4416	1.6731	0.9769	2.0187	1.860	1.714	1.282	2.326	8	23	39	10	No	No	No	No
7.	WK (67) vs. WK X-VAL (L.S.)	1.2342	0.3580	0.5702	2.0758	1.372	1.319	1.282	2.326	10	23	37	76	No	No	No	No
8.	WK (51) vs. WK X-VAL (L.S.)	1.2343	0.3580	0.5702	0.5102	1.372	1.319	1.282	1.282	10	23	37	60	No	No	No	No
9.	WK (67) vs. WK X-VAL (R.S.)	1.0363	0.6426	0.0281	2.8567	1.415	1.337	1.282	2.576	7	16	39	73	No	No	No	Yes
10.	WK (51) vs. WK X-VAL (R.S.)	1.0363	0.6426	0.0281	1.3534	1.415	1.337	1.282	1.645	7	16	39	57	No	No	No	No
11.	WK (51, L.S.) vs. WK X-VAL (L.S.)	-	1.0374	0.3827	0.5037	-	1.333	1.318	1.282	-	17	24	35	-	No	No	No
12.	WK (51, R.S.) vs. WK X-VAL (L.S.)	-	0.5723	0.7073	0.4360	-	1.341	1.325	1.313	-	15	20	28	-	No	No	No
13.	WK (51, R.S.) vs. WK X-VAL (R.S.)	-	0.0371	0.2351	1.2130	-	1.397	1.321	1.316	-	8	22	25	-	No	No	No
14.	WK (51, L.S.) vs. WK X-VAL (R.S.)	-	1.0868	0.1417	0.3246	-	1.372	1.315	1.282	-	10	26	32	-	No	No	No
15.	WK (51, L.S.) vs. WK (51, R.S.)	-	1.3022	0.4545	1.2161	-	1.356	1.313	1.282	-	12	28	43	-	No	No	No

* WTD - WHITEMUD TERRACES
WK - WEED CREEK TERRACES
X-VAL - CROSS-VALLEY PROFILE TERRACES
B.S. - BOTH SIDES
R.S. - RIGHT SIDE
L.S. - LEFT SIDE

** All Terrace Measurements
*** All Terrace Measurements Except Those Less Than 9% of Valley Depth

tal with the preglacial Thorsby thalweg. Also, no significant difference is observed when the Weed Creek terraces (51) are compared with the Whitemud terraces (Table 3:5, No. 6) and the Weed Creek cross-valley profile terraces (Table 3:5, No. 8). Consequently, the terraces in this section of the stream should either not fit or only partially fit into the designated terrace levels.

The section between knickpoints 1 and 2 (Fig. 3:1) appears to be the most stable part of the valley which includes the cross-valley profiles 4 - 8.

The results of Table 3:5 strongly suggest cyclic significance of the Weed Creek terraces and a close similarity with the cyclic terraces of the Whitemud basin. The normal distribution of the Weed Creek alluvial deposit thickness implies even thicknesses of these deposits in three of the terrace levels and as such satisfies one of the added criteria for cyclic terrace development. These deposit thicknesses also bear a close similarity with the Whitemud terrace deposits.

In most cases observed along the stream channel, alluvial deposits were seen in the upper sections of the terraces. From the photos of the study area (p. 78), it can be seen that the upper sections of the terraces are alluvial and as such are of the alluvial sub-group. Along the clearly cut terrace banks, coarse stream gravels were observed lying above sharply defined bedrock levels. The alluvial deposits, though not sampled in detail,

showed a fining upwards of sands, silts and clays in almost every field plot observed. The sands in many cases were rippled, indicative of deposition by a fairly fast flowing stream and the silts and clays portrayed a vertical accreted character which is representative of deposits laid down in standing or very slow moving waters. Also, no evidence along the stream channel of a thin veneer of contemporaneous gravels or alluvium on the tread surfaces was observed to indicate a difference in cycle to that of the main terrace fills. All this suggests that the terraces are Depositional.

Bedrock and Terrace Height Plots

Bedrock and terrace heights between cross-valley profiles 4 to 8 were plotted based on the present stream profile (Figs. 3:5.1, 3:5.2, 3:6.1 and 3:6.2). The figures show left and right bank distributions. Terrace and old channel heights from the cross-valley profiles were added and, actual alluvial deposit thicknesses were also added (to some of the bedrock heights), and symbolized. The bedrock and terrace levels are mean values, each depicting an upper and lower limit.

From observations of the bedrock height diagrams, the designated groupings of the heights are graphically displayed. Four other points can be further observed. Some terrace tread surfaces which fall within a particular

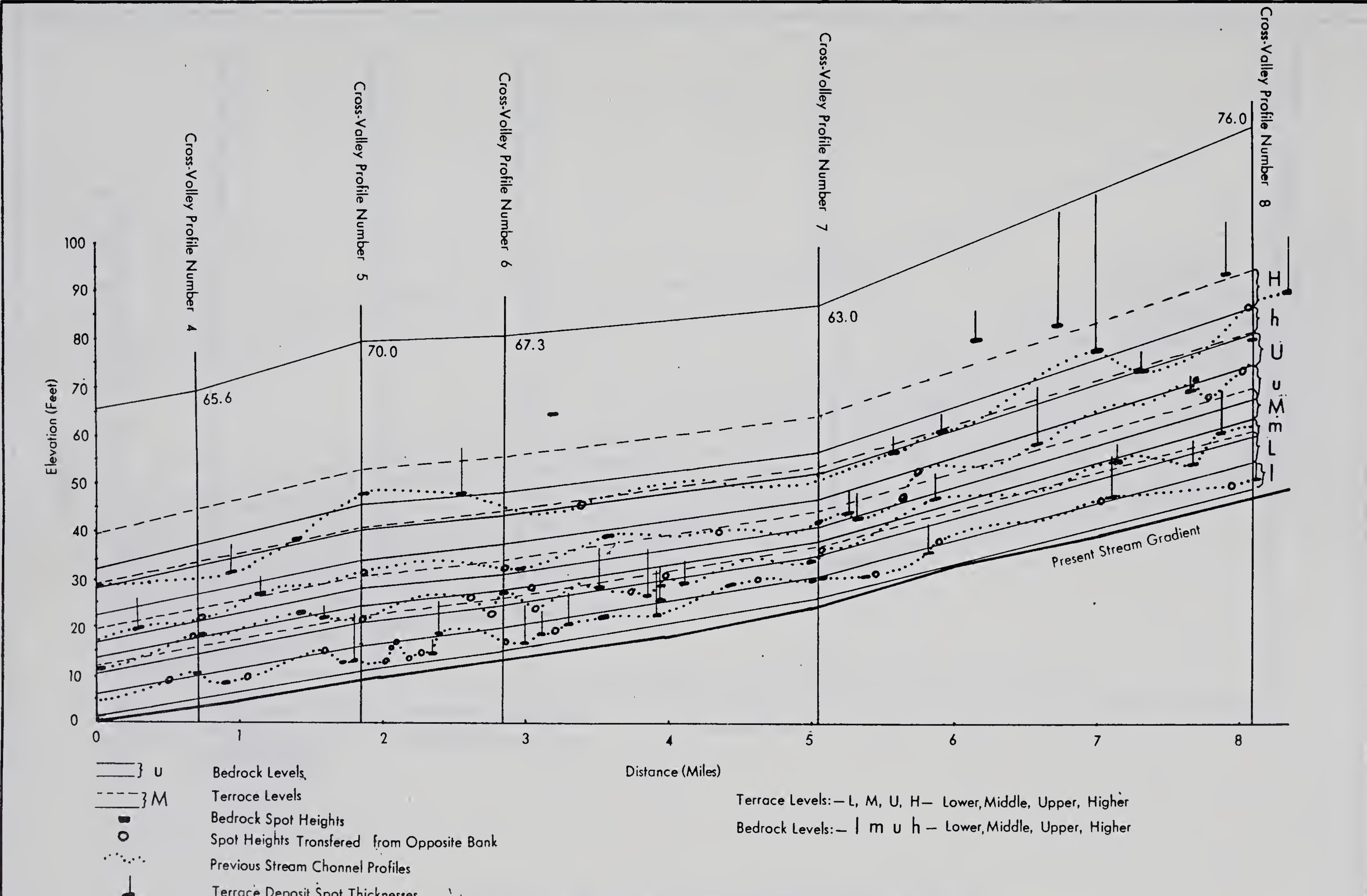


Figure 3:5.1 Bedrock Heights-Left Bank.

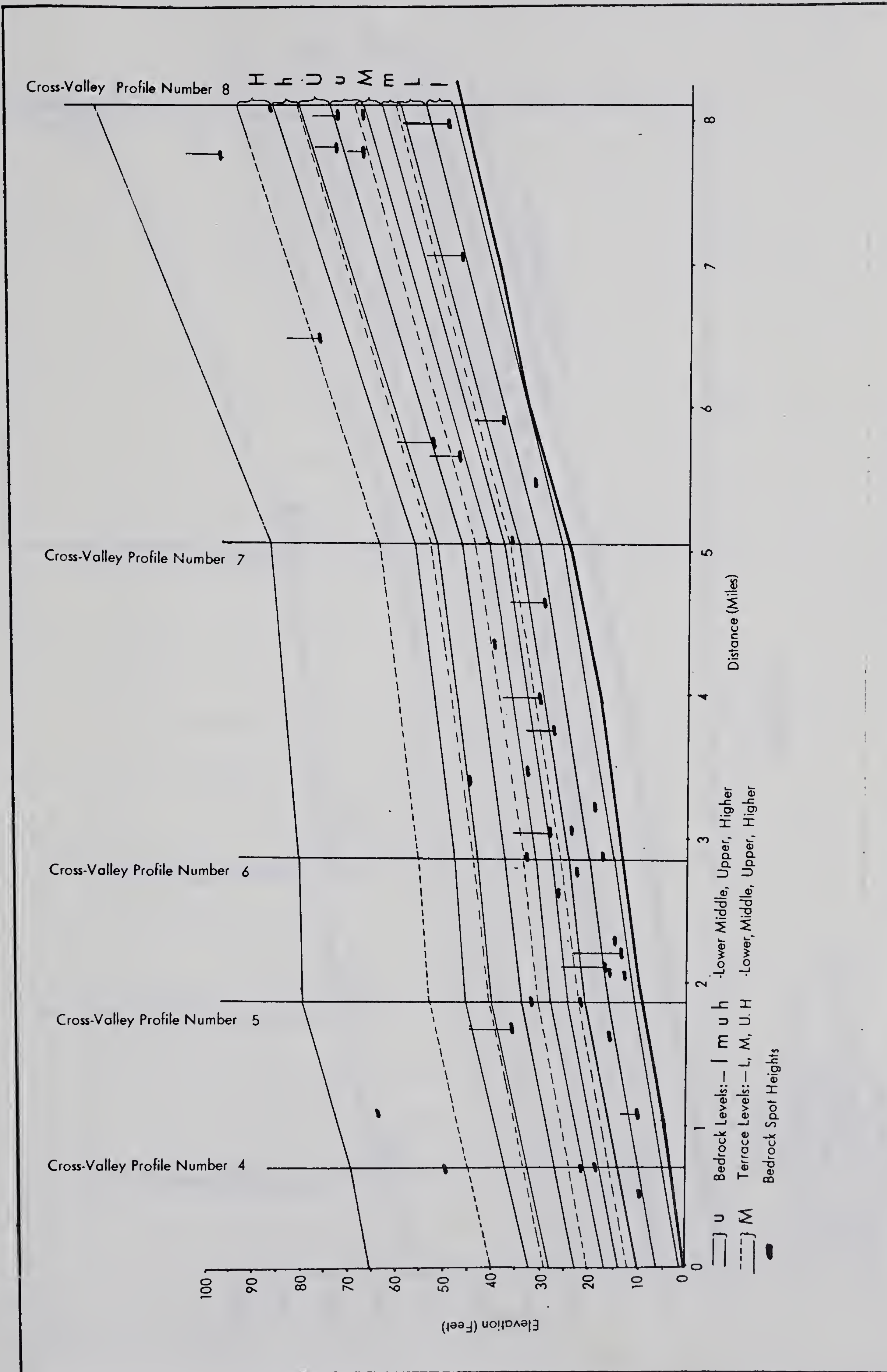


Figure 3:5.2 Bedrock Heights-Right Bank

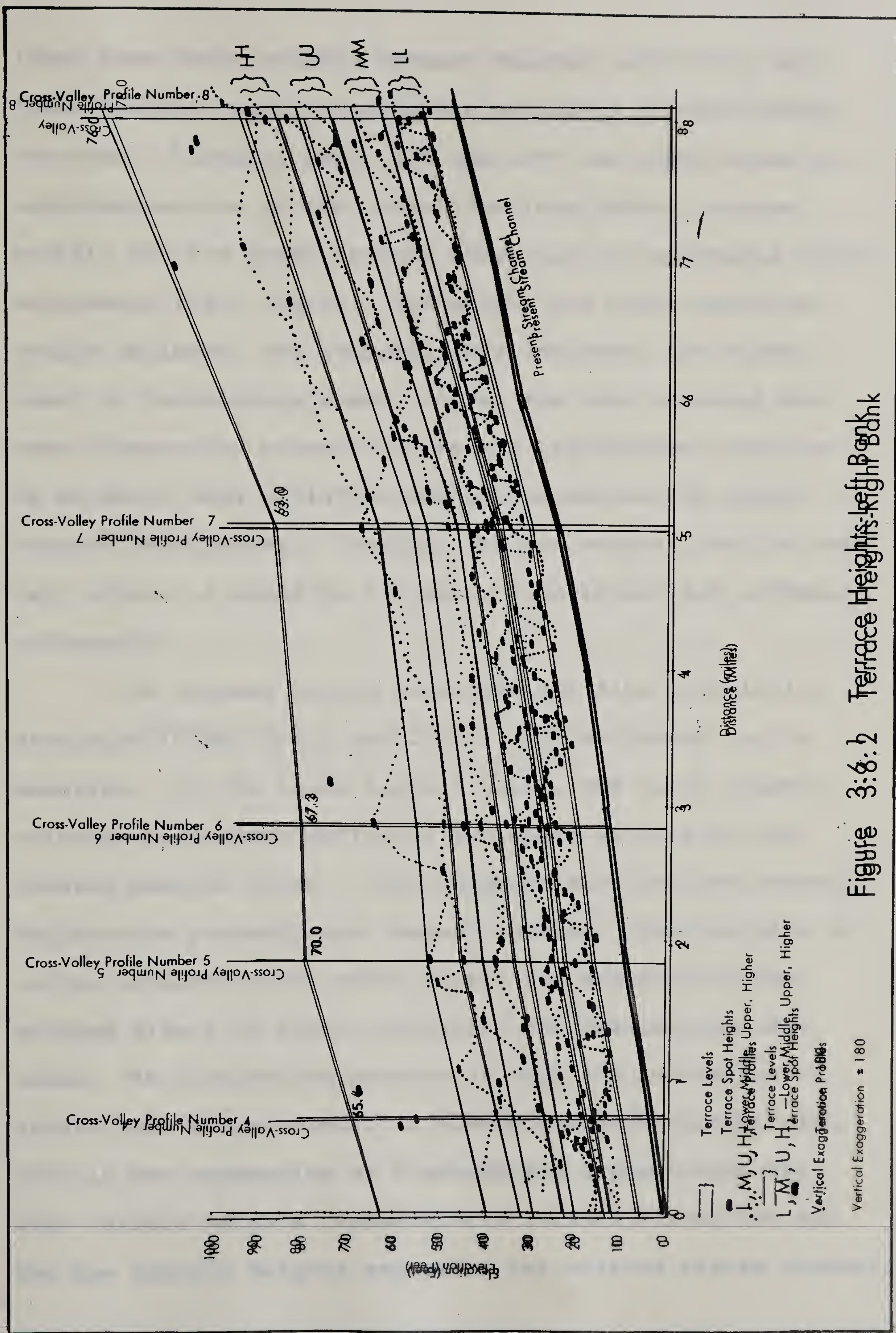


Figure 3:6:1 Terrace Heights-Left Bank
Figure 3:8:2 Terrace Heights-Right Bank

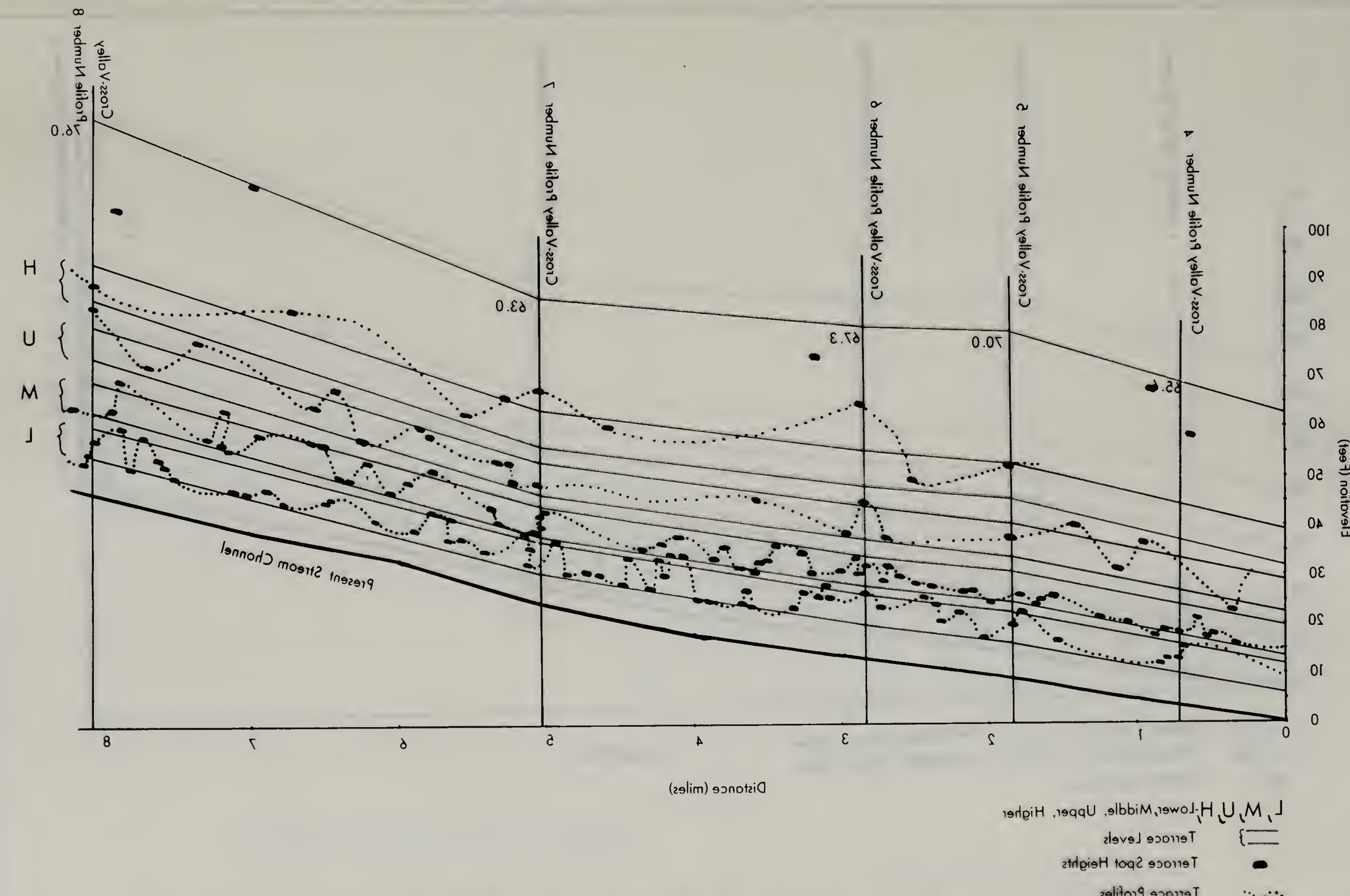


Figure 3:6.1 Terrace Heights-Left Bank

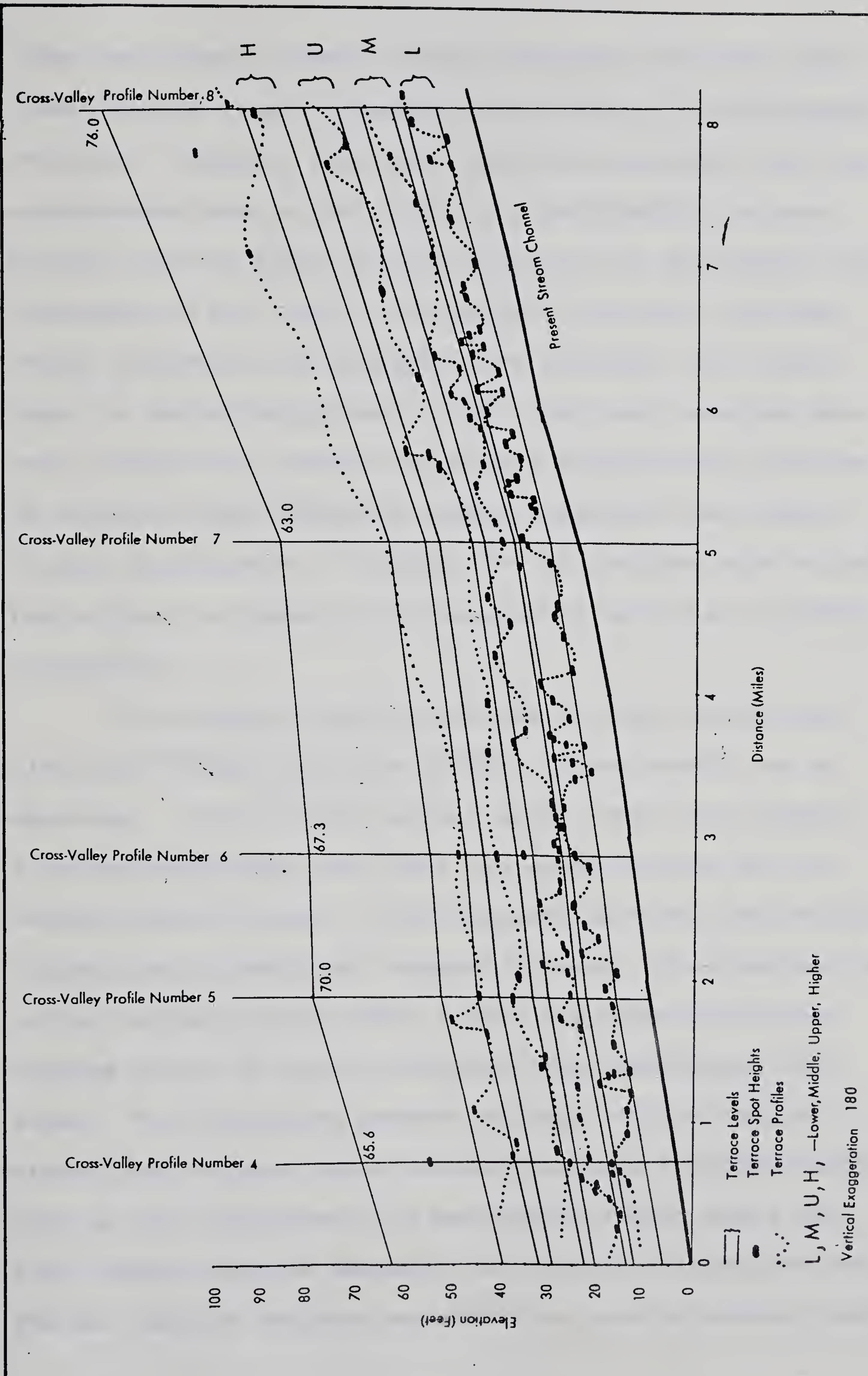


Figure 3:6.2 Terrace Heights-Right Bank

level have their related bedrock heights within the next lower bedrock level, showing the existence of overlapping terraces. Further, when both the left and right sides are superimposed one on the other, the longitudinal stream profile for the lower terrace level can be reproduced fairly accurately (Fig. 3:5.1). The middle and upper profiles, though reliable, are probably less accurate; the higher level is tentatively drawn. Also, the near parallel pattern between the present and former longitudinal profiles is evident; this satisfies another criterion for cyclic terrace development. Finally, the few heights that do not fall within or close to the designated levels are probably non-cyclic.

The terrace height groupings are also graphically displayed (Figs. 3:6.1 and 3:6.2). Three points can be observed. In the lower terrace level, the lower heights coincide reasonably well with the upper heights of its related bedrock level. This suggests that the low terrace heights are probably old channel courses. This pattern is not as evident in the other levels due probably to the masking effect of minor non-cyclic and overlapping terraces. An alternating pattern of high and low heights within each terrace level is also observed longitudinally. This is the expression of a meandering stream where the high terrace heights represent its related floodplain and the low terrace heights represent its related stream channel.

Finally, when the left side terraces are superimposed on the right side terraces, the high and low terrace heights, within each level, are out of phase with each other, i.e., the high points on one side coincide with the low points on the other. This supports the fact that the related streams for each level were meandering and indicates that the lateral and vertical accretion deposits should be evident in the terraces' stratigraphy. Though no complete detailed terrace deposit study was undertaken, deposits observed in the field displayed a sequence of gravels on bedrock, where exposed, overlain by stream deposited sands and silts--lateral accretion--which in turn are overlain by vertically deposited silts and clays from periodic flooding.

Description of the Cross-Valley Profiles
(See Figs. 3:7.1-3:7.8)

The description of the cross-valley profiles also supports the argument for a cyclic development of the Weed Creek terraces. The old channels of the designated terrace levels frequently fall within their related bedrock intervals and their terrace tread features fall generally within their related terrace intervals. Also most of the terrace tread surfaces display a striking horizontal attitude, another criterion for cyclic terrace development. Figures 3:7.1 to 3:7.8 show these two important relationships. (Note: The designated sides of the cross-valley

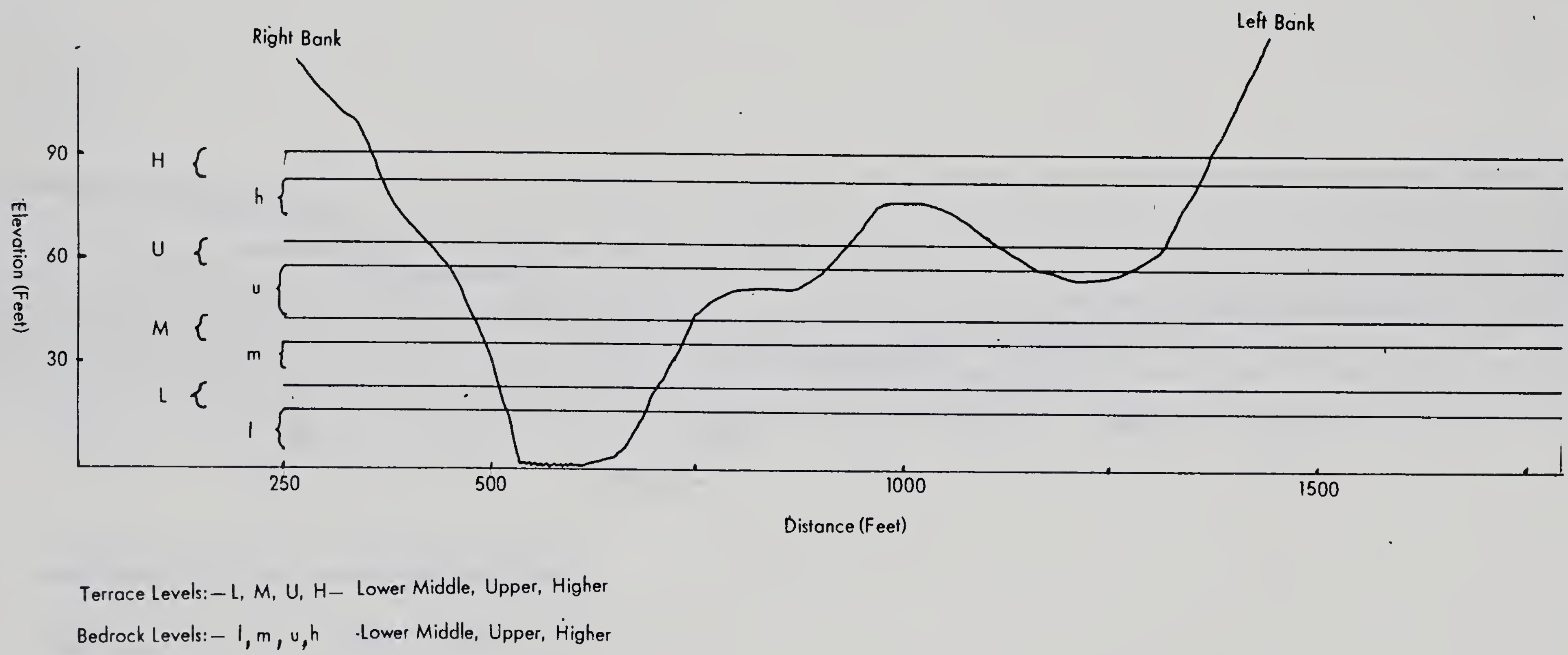


Figure 3:7:1 Cross-Valley Profile Number 1

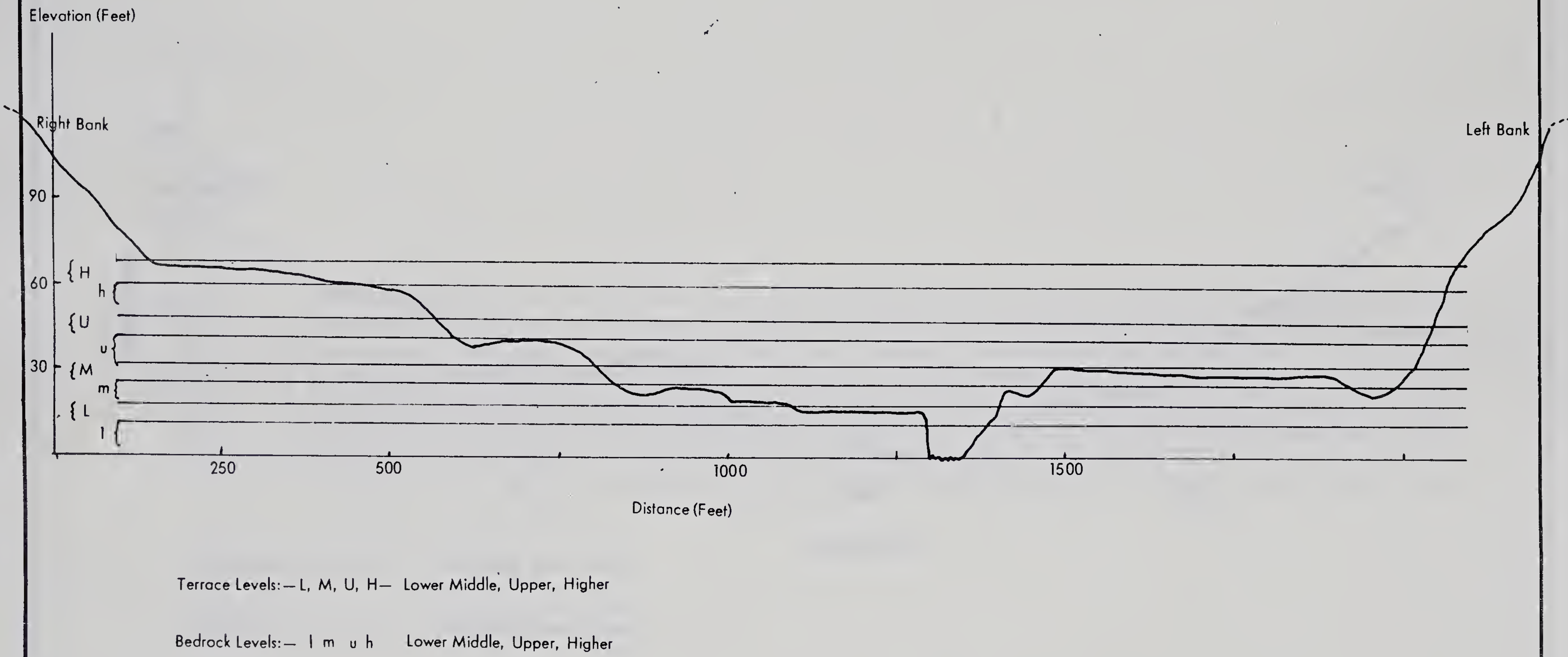


Figure 3:7.2 Cross-Valley Profile Number 2

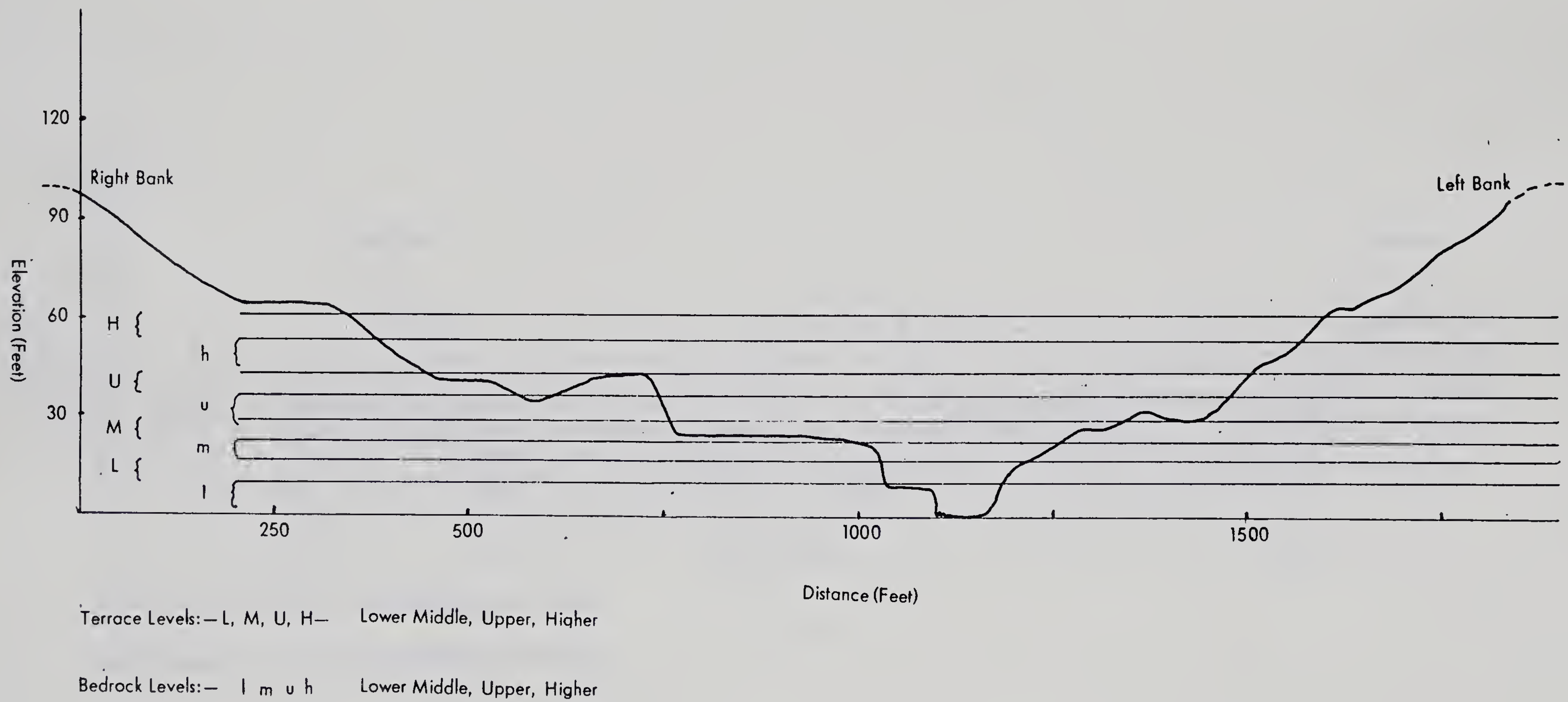
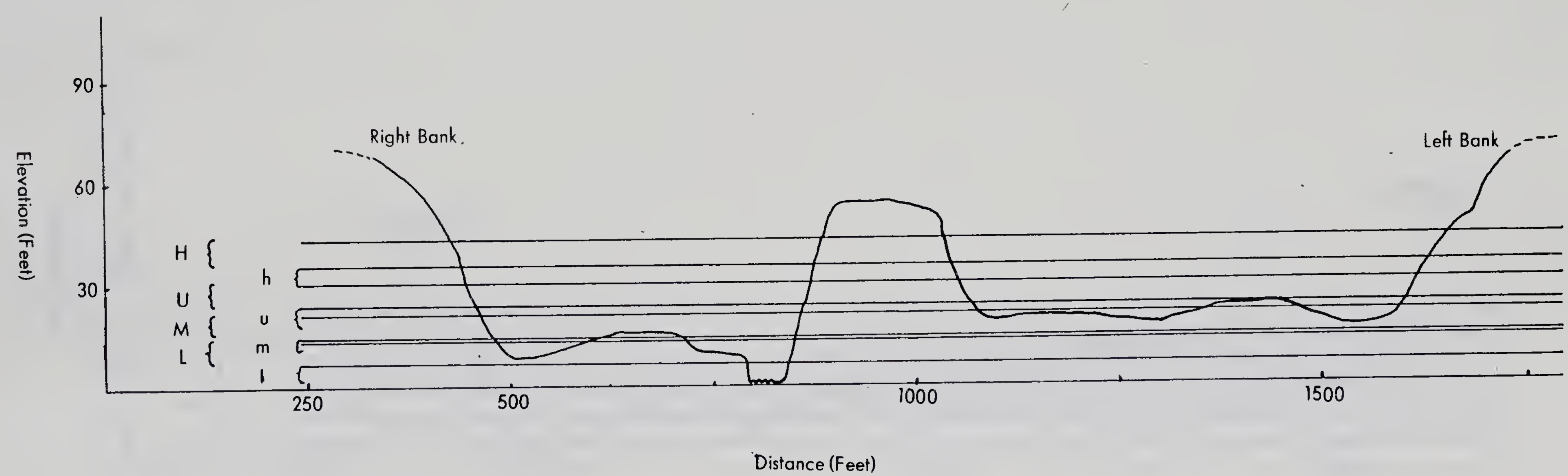


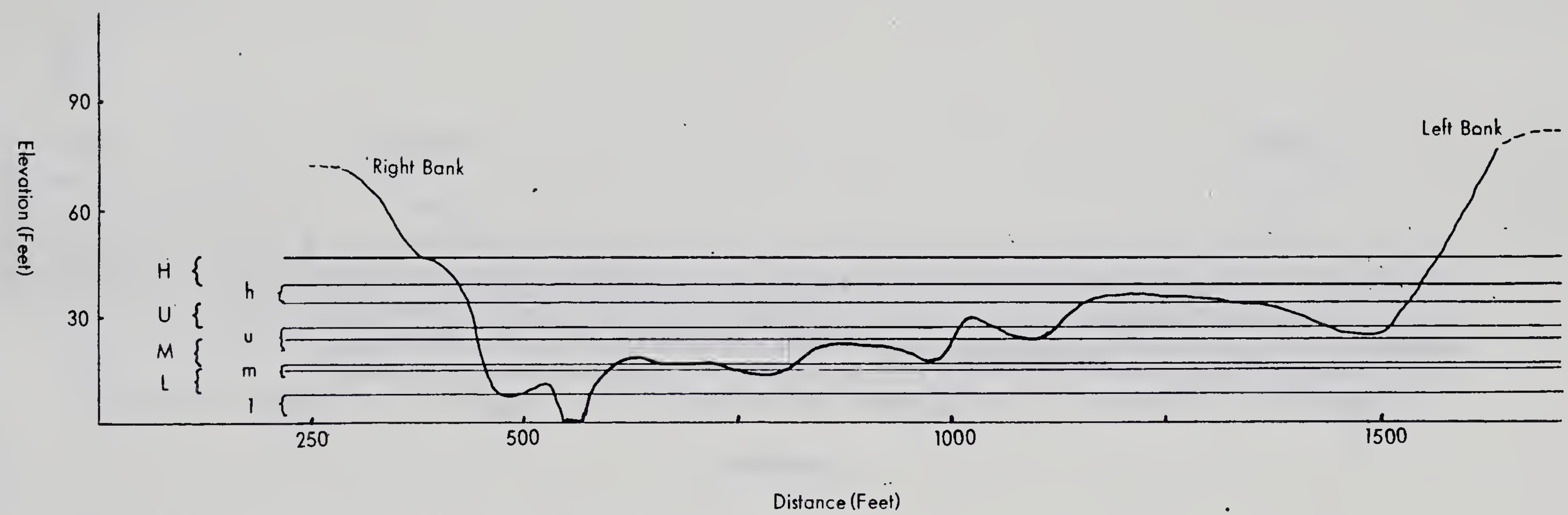
Figure 3:7:3 Cross-Valley Profile Number 3



Terrace Levels: — L, M, U, H— Lower Middle, Upper, Higher

Bedrock Levels: — l m u h Lower Middle, Upper, Higher

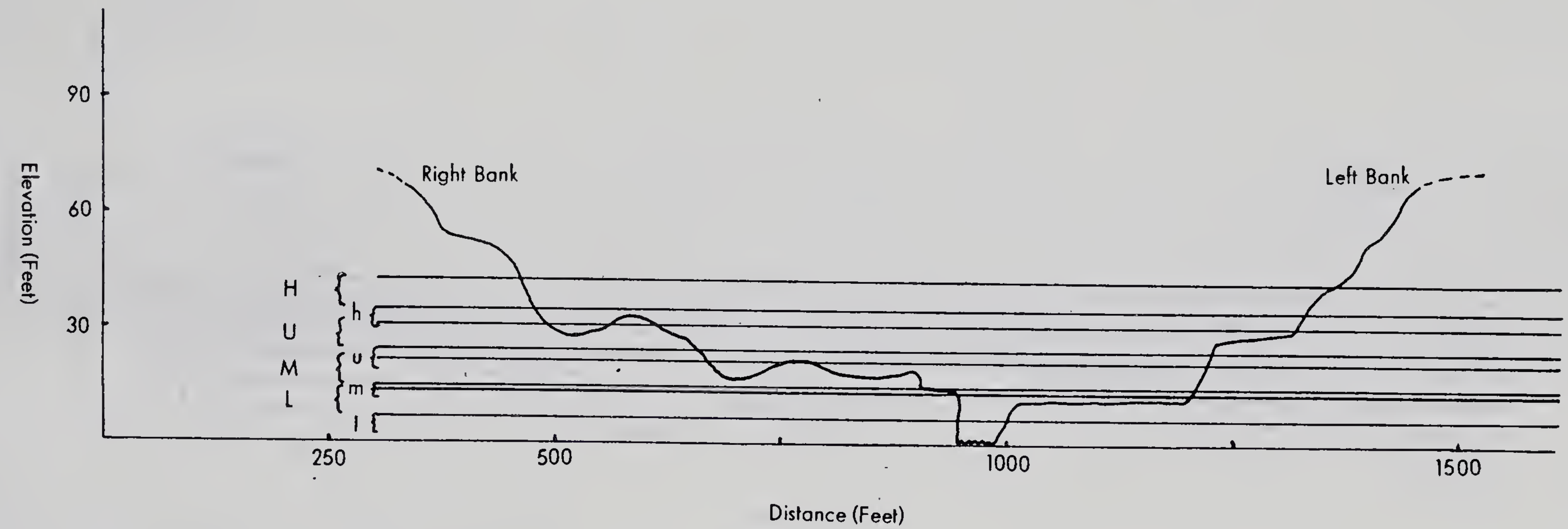
Figure 3:7.4 Cross-Valley Profile Number 4



Terrace Levels: — L, M, U, H — Lower Middle, Upper, Higher

Bedrock Levels: — l m u h Lower Middle, Upper, Higher

Figure 3:7.5 Cross-Valley Profile Number 5



Terrace Levels:— L, M, U, H— Lower Middle, Upper, Higher

Bedrock Levels:— l, m u h Lower Middle, Upper, Higher

Figure 3:7.6 Cross-Valley Profile Number 6

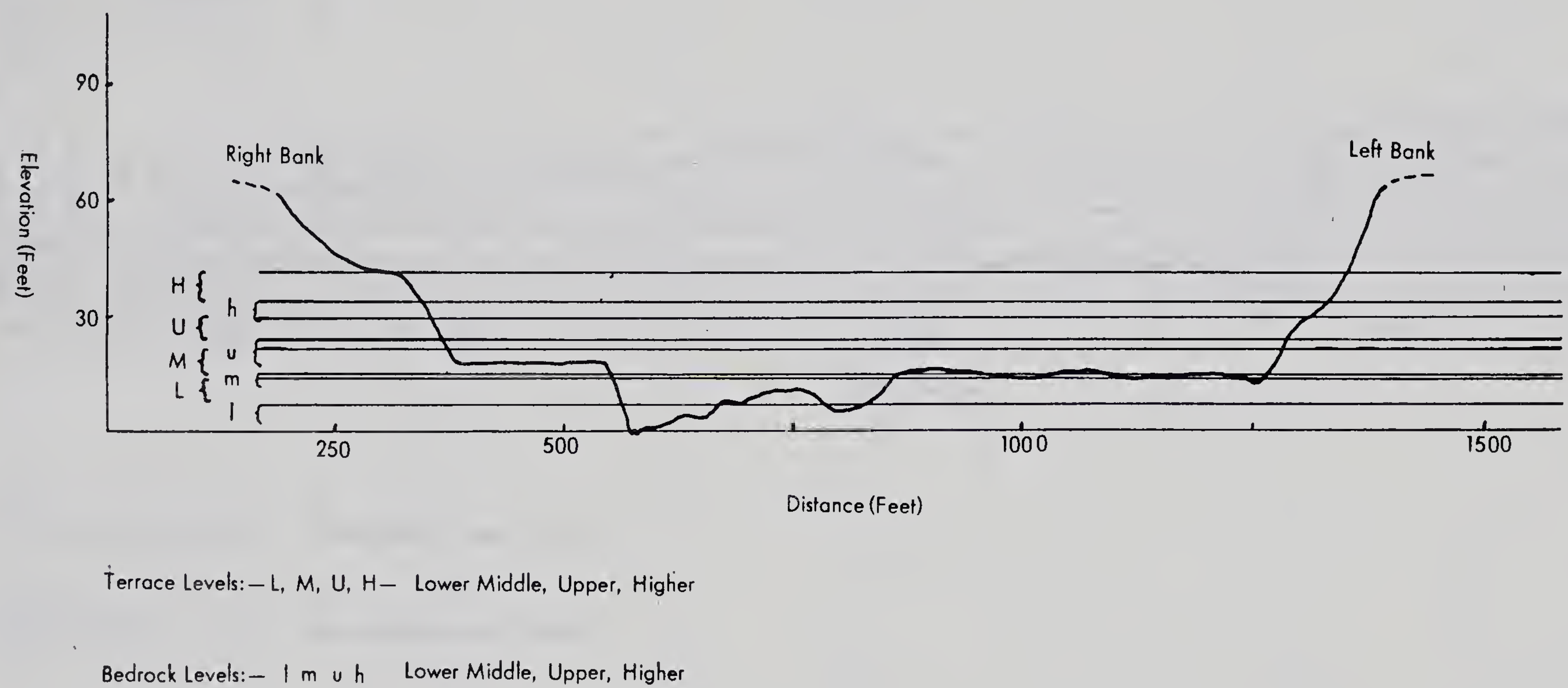


Figure 3:7.7 Cross-Valley Profile Number 7

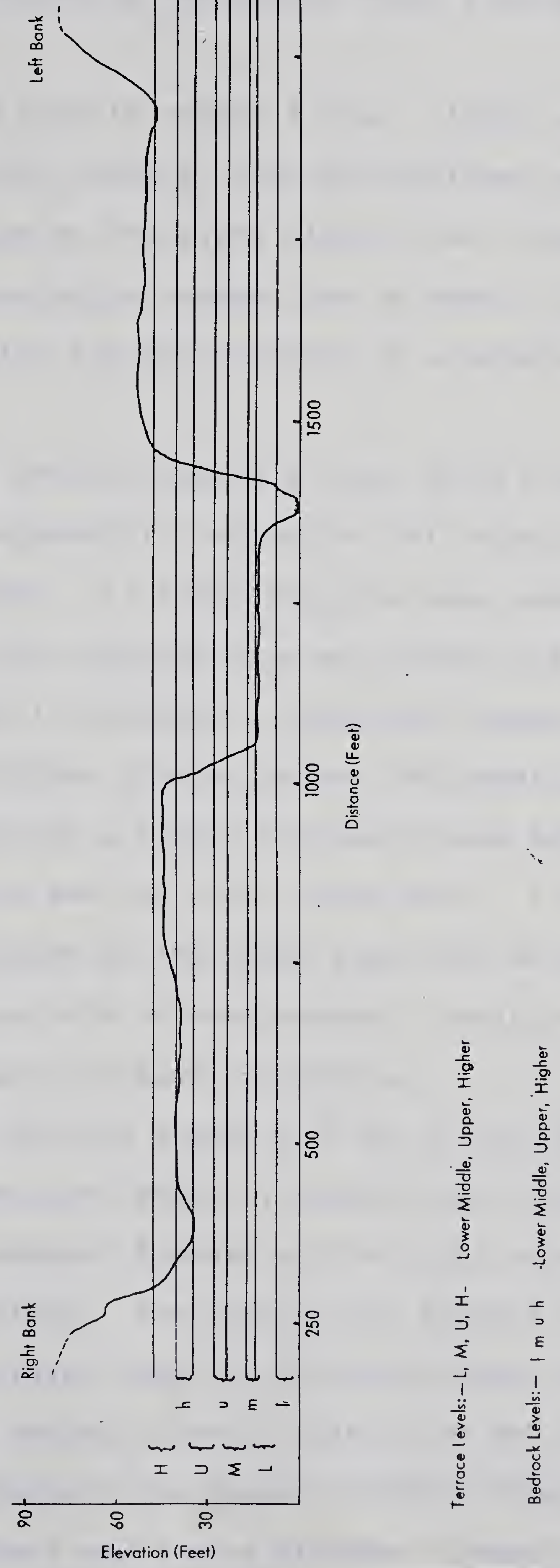


Figure 3:7.8 Cross-Valley Profile Number 8

profiles were determined by the author while looking downstream).

Cross-valley profile number 3 (Fig. 3:7.3) appears to have a higher level terrace, with well-defined upper and middle level terraces on the right side of the valley; on the left side, a non-cyclic terrace can be seen. The lower level terrace is quite low and probably is a related old channel.

Cross-valley profile number 4 (Fig. 3:7.4) has a resistant feature adjacent to and on the left side of the present stream channel. It definitely has been shaped by fluvial action but its altitude lies well above the higher terrace level. This is probably a resistant bedrock feature but requires further investigation. No upper level terrace is preserved but a middle terrace occurs between the resistant feature and the left valley wall. A lower level terrace is evident on the right side with an overlapping character and with related channel levels on both sides at approximately the same elevation.

Cross-valley profile number 5 (Fig. 3:7.5) has no higher level terraces preserved; it has not been determined whether or not the remnant feature on the right side is a terrace or slump feature. The upper level terrace on the left side has its related channels falling between the limits of the upper bedrock level. Point 3 on the right side of the valley depicts the lowest probable height that the upper level channel could have attained (Leopold _et al_,

1964). A middle terrace is preserved on the left side of the present stream with its related channels falling within the middle bedrock level. A lower terrace remnant on the right side along with its related channel also fit the lower terrace and bedrock levels quite well.

The cross-valley profile number 6 (Fig. 3:7.6) has a higher level terrace preserved. An upper level is also fairly well preserved on both sides of the valley and was probably formed by its related stream meandering laterally from right to left then to the right again. A middle terrace is only preserved on the right side with its related channels on both sides of the remnant terrace at approximately equal elevation. A non-cyclic terrace remnant lies adjacent to the present stream on the right side with a lower terrace very well defined by its horizontal tread surface.

Cross-valley profile number 7 (Fig. 3:7.7) portrays a higher terrace remnant on the right side. No upper terrace is preserved but the middle terrace level is well displayed on both sides; its horizontal tread surface is indicative of a meandering stream in steady state with its lowest channel, on the extreme left side, falling within the middle bedrock interval. The lower terrace along with its related channel on the left side of the present stream fits the designated terrace and bedrock levels quite well.

Cross-valley profile number 8 (Fig. 3:7.8) has a

well defined higher terrace on both sides of the valley. It was formed when the stream was in a meandering state; alluvial deposits related with these terraces show vertical accretion patterns underlain by lateral accretion patterns. There are no upper and middle terraces preserved but the lower terrace on the right side displays a distinctly horizontal profile.

Cross-valley profiles numbers 1 and 2 (Figs. 3:7.1 and 3:7.2) show slight deviations from the designated terrace levels. The entrance of large tributaries just above these profiles (Fig. 3:2), no doubt, contributes greatly to the discharge of the stream, thus increasing, by itself or along with the probable reasons (p.56) of rejuvenation and coincidental stream position with the preglacial Thorsby thalweg, the incision rates downstream from these areas.

Planimetric Distribution of the Weed Creek Terraces

Terrace heights were plotted along the present stream channel as shown in Figure 3:8. Figures 3:8.1 - 3:8.7 are enlargement sections of Fig. 3:8. Sections 4 to 7 encompass that part of the stream where cross-valley profiles 4 (Fig. 3:8.4-3:8.7) to 8 are situated and it is along this part of the stream that the planimetric mapping of the different terrace levels is displayed. The lower and middle terraces are numerous and well distributed with

Figure 3:8 Planimetric Map of Sudy Area

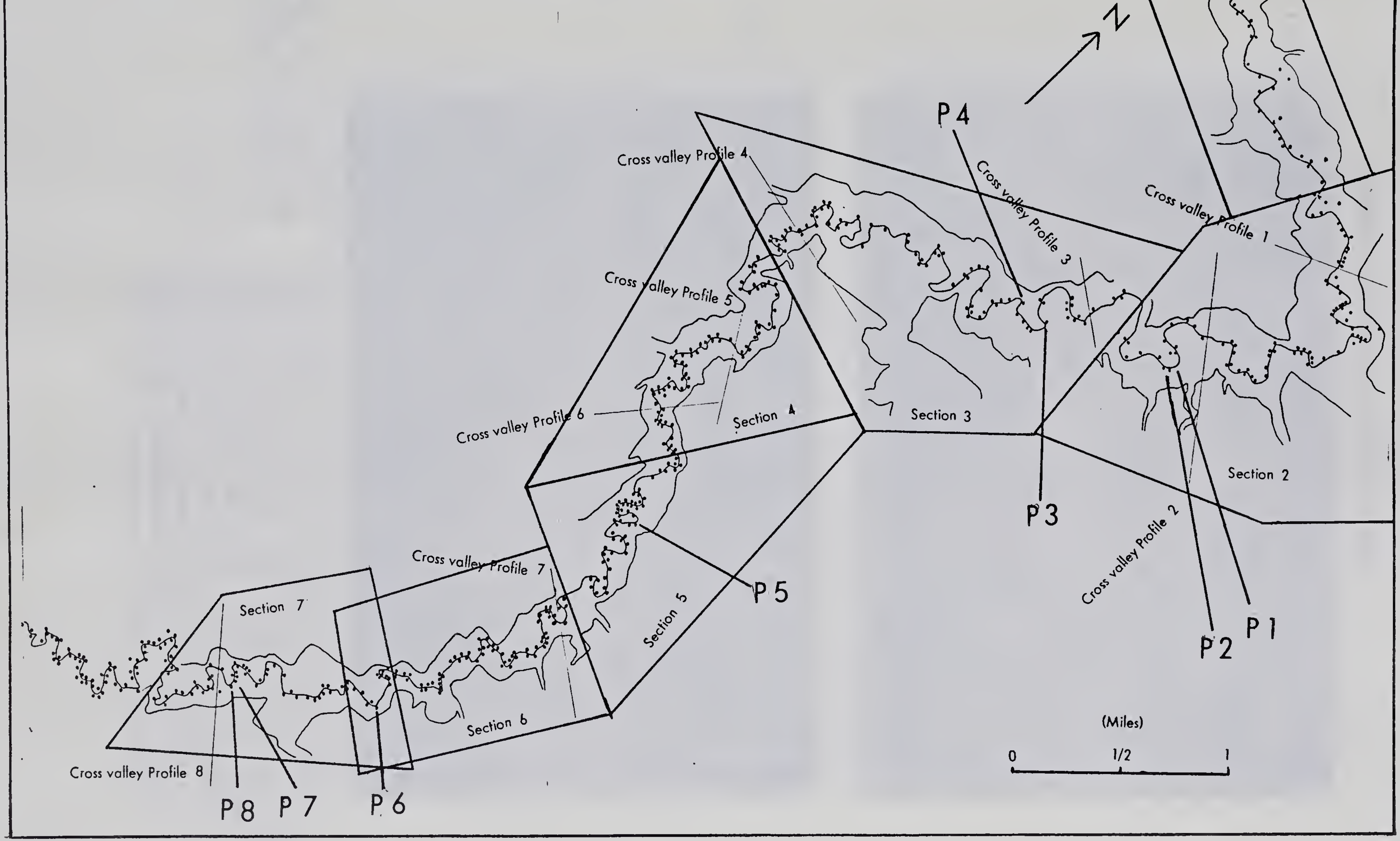


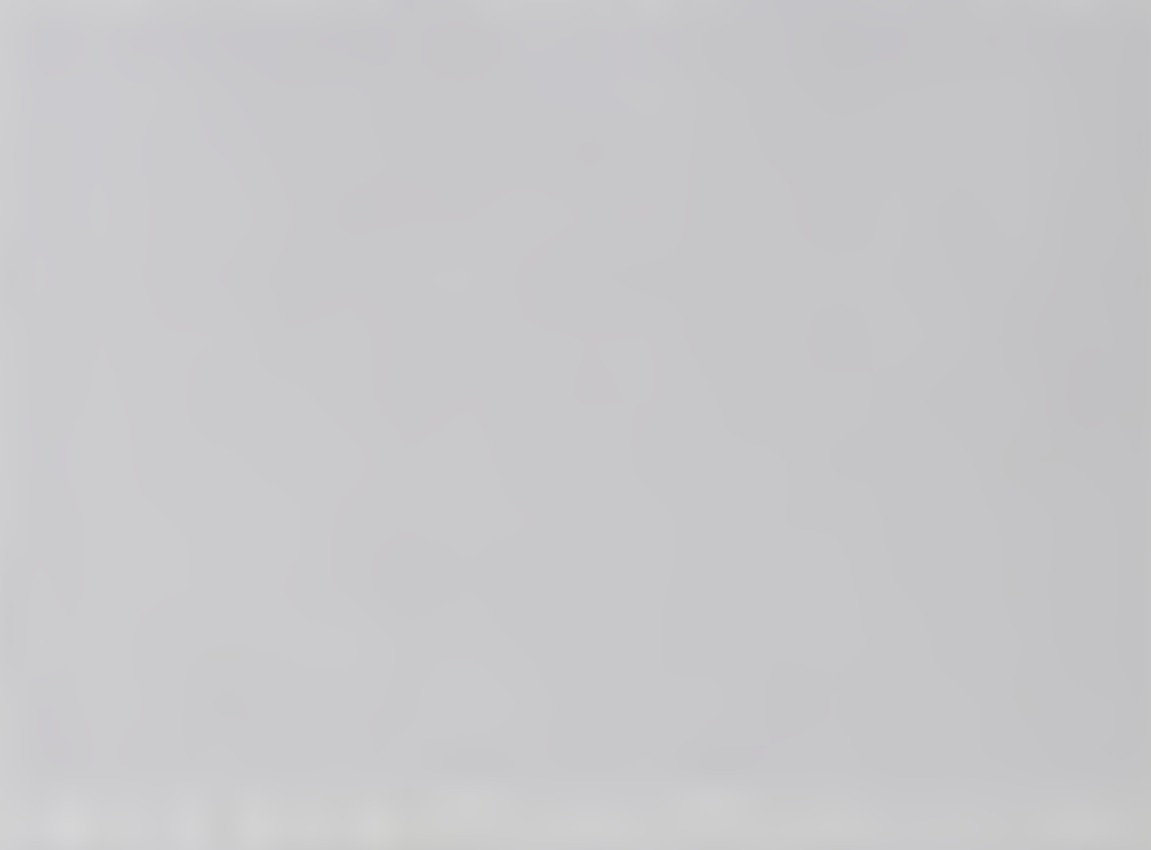
PHOTO PLATES OF STUDY AREA

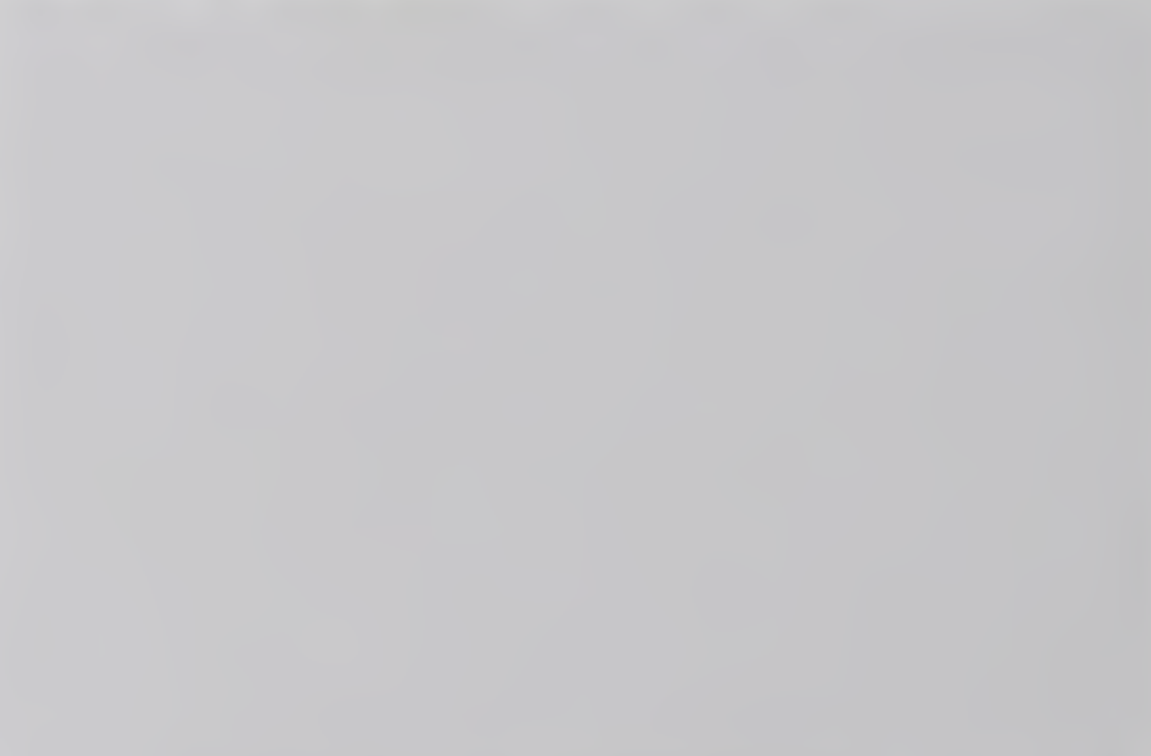
1.

2.

Plates 1, 2 and 3
(See P1 on Fig. 3:8
and Fig. 3:8.2)

An upper level terrace (35-36 feet) upstream from and related to the upper level terrace on the right bank of the cross-valley profile number 2. Note the distinct contact between bedrock and stream gravels and the thick alluvial deposits above. Note also the flat horizontal tread surface.





3.

4.

Plate 4
(See P2 on Fig. 3:8
and Fig. 3:8.2)

A continuation of the above-mentioned upper terrace. It displays the definite break of slope that is typical between the terrace levels of the Weed Creek basin. The lower terrace extends upstream at an average height of 15 feet.

5.

6.

7.

Plates 5, 6 and 7
(See P2 on Fig. 3:8
and Fig. 3:8.2)

Number 5--Upstream extension of the lower terrace in photo number 4. The gravels lying on bedrock are of Shield and Rocky Mountain origins--typical of the gravels in all levels of terraces. Imbrication upstream can be seen--also observed throughout the basin. Lying on the gravels are the laterally accreted sands and silts overlain by the vertically accreted silts and clays. Note exposure of extinct bison specimen. Number 6--A distant view of faunal specimen and terrace cut. Number 7--An upstream extension of this lower terrace.

8.

Plate 8 Author with faunal specimen--extinct bison scapula.

9.

Plate 9
(See P3 on Fig. 3:8 and 3:8.3)

An upper level terrace--38 feet. The only evidence found of gravels separated from bedrock by stream laiden rippled sands.

10.

Plate 10

Upstream from terrace in photo number 9, the distinct break in slope separating an upper, middle and lower terrace is distinct. Note the flat horizontal tread surface of the middle terrace.

11.

Plate 11
(See P4 on Fig. 3:8 and 3:8.3)

Lower terrace--10 feet depicting the shelter and protection of terrace scarps for the nesting of young birds.

12.

Plate 12
(See P5 on Fig. 3:8 and 3:8.5)

A middle terrace (16-18 feet) displaying the upward sequence of bedrock, gravels, rippled sands and thick vertically deposited silts and clays. It is a characteristic display of the Weed Creek cyclic depositional terraces.

13.

Plate 13
(See P6 on Fig. 3:8
and 3:8.7)

A higher terrace (46-47 feet). The regular bedrock, gravels and alluvium is discernible; also the flat horizontal tread surface.

14.

Plate 14
(See P7 on Fig. 3:8
and 3:8.7)

An exhibit of an upper, middle and lower terrace. Also note the upper terrace (top left picture) on opposite bank.

15.

Plate 15
(See P8 on Fig. 3:8
and 3:8.7)

A middle terrace (18-20 feet). An upward sequence of bedrock, till, gravels and alluvial deposits can be seen.

16.

Plate 16
(See P9 on Fig. 3:8
and 3:8.7)

A lower terrace just downstream from cross-valley profile number 8.

Figure 3:8.1 Planimetric Map Number 1

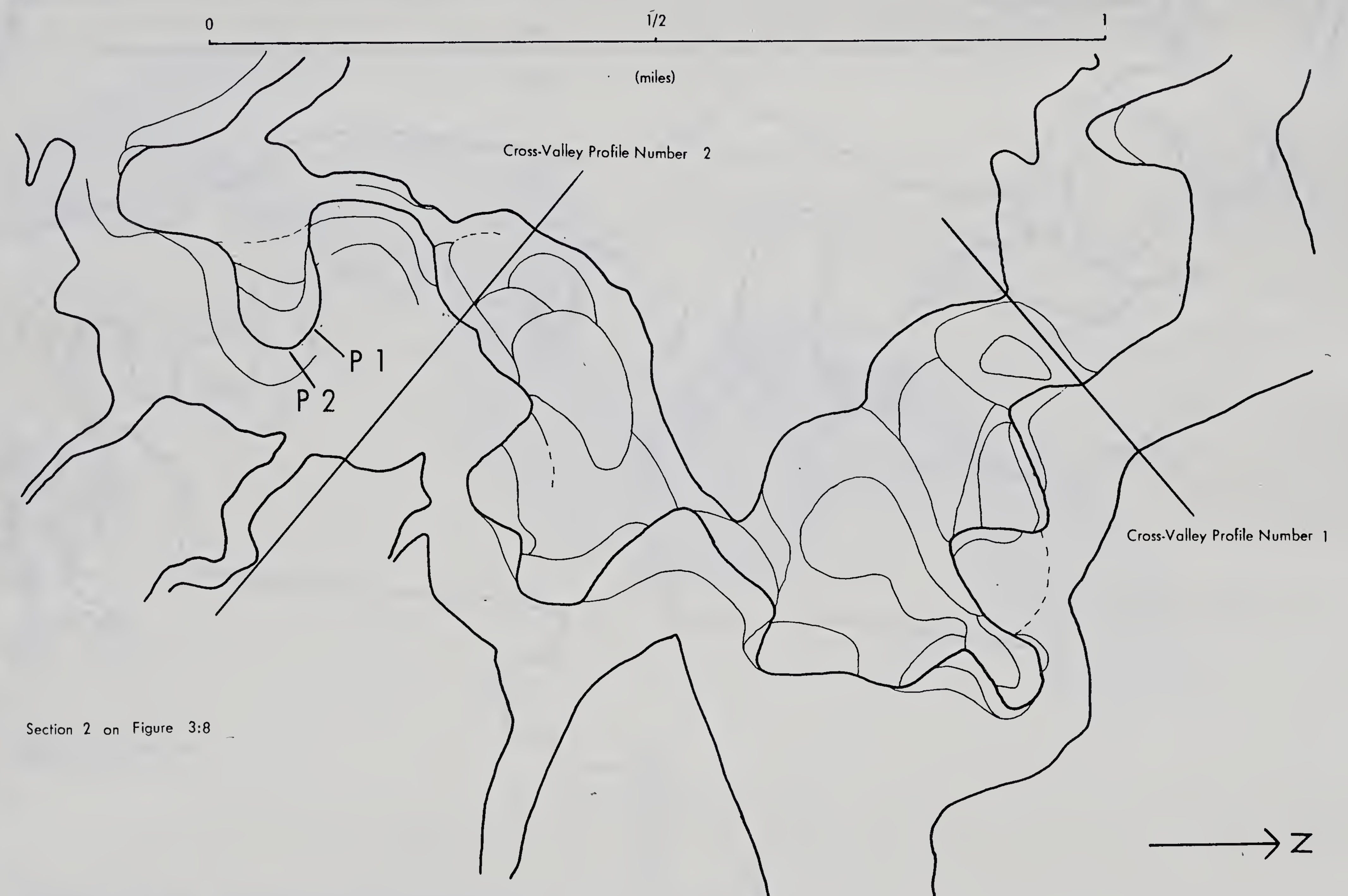


Figure 3:8.2 Planimetric Map Number 2

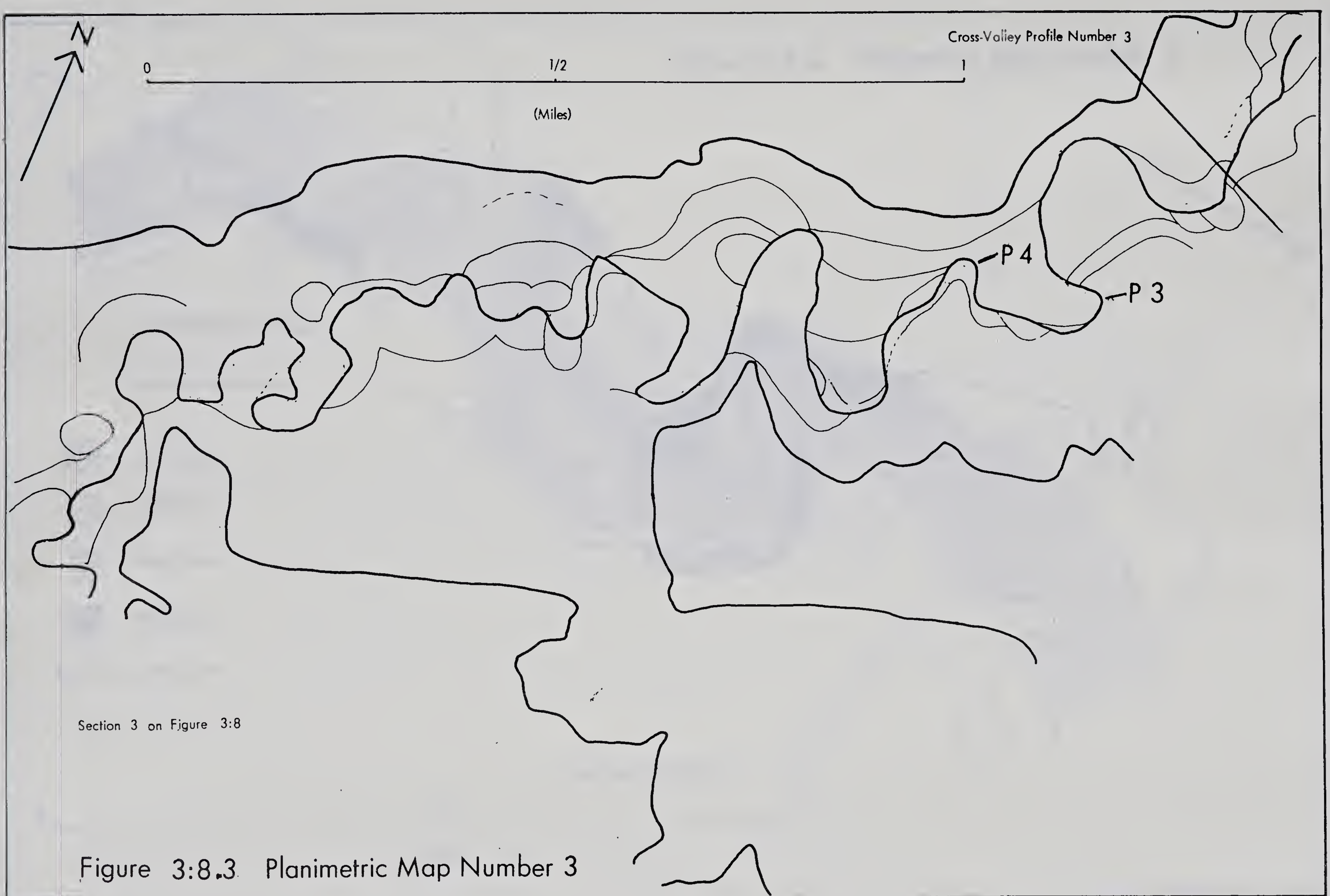
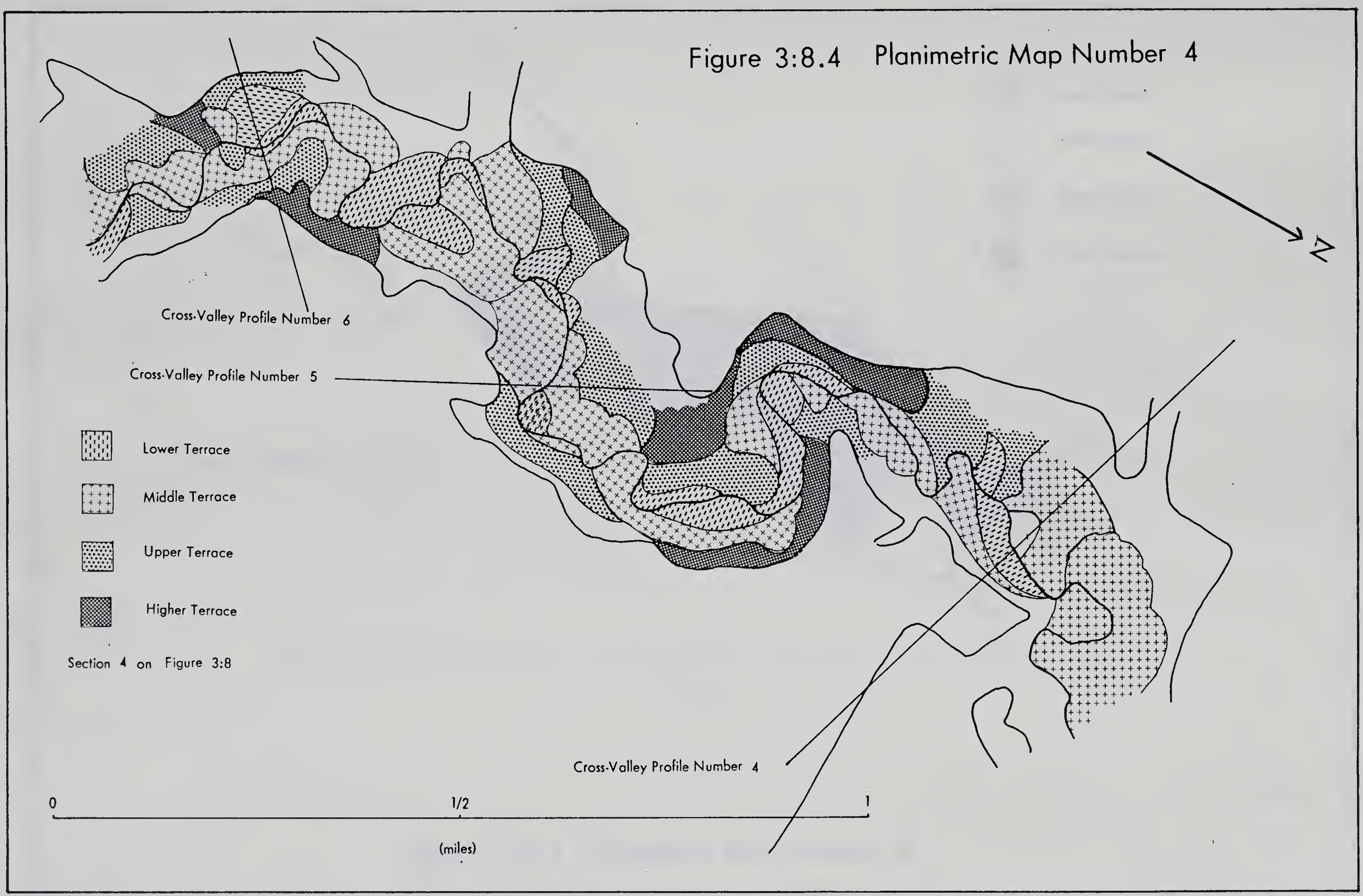


Figure 3:8.3 Planimetric Map Number 3

Figure 3:8.4 Planimetric Map Number 4



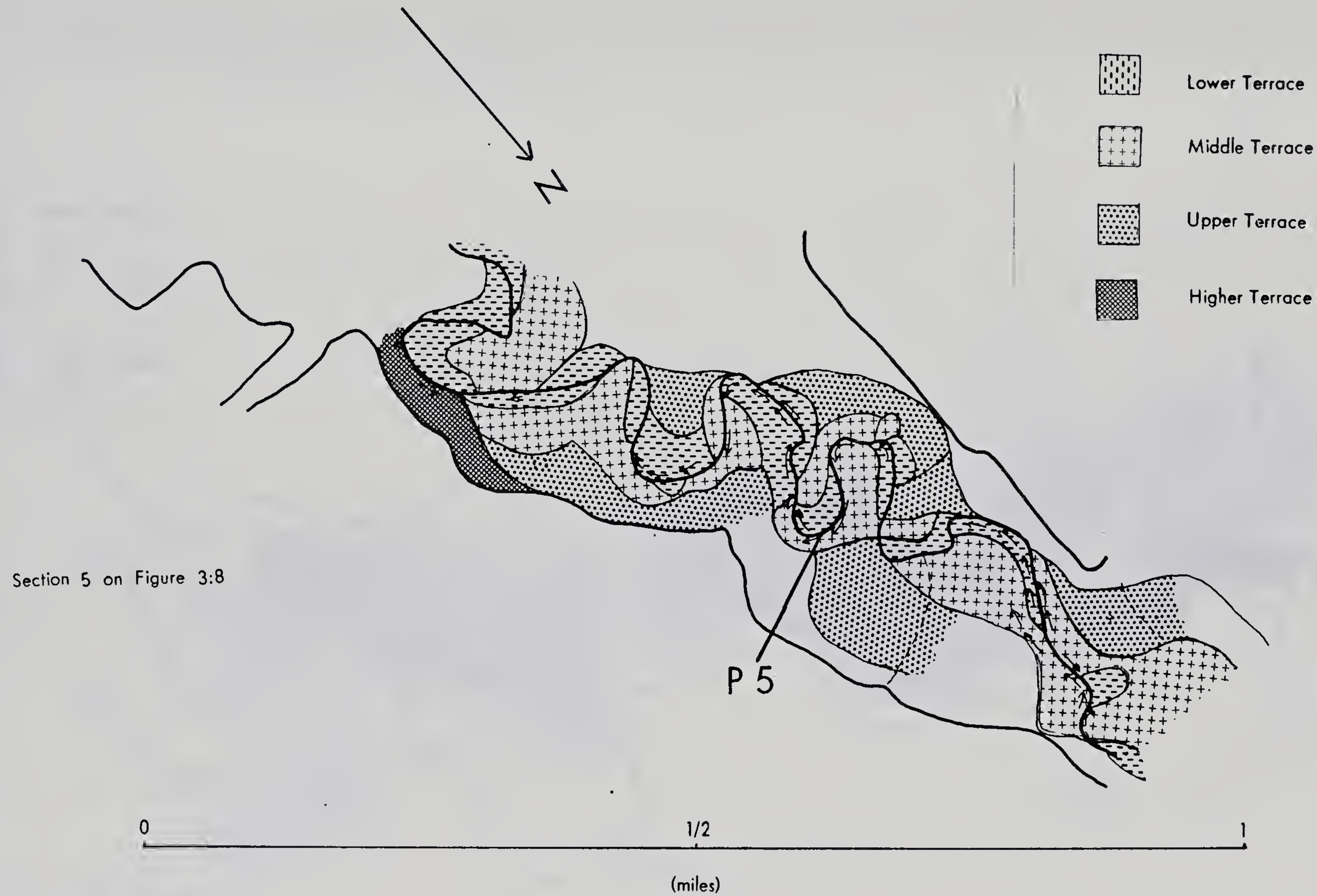


Figure 3:8.5 Planimetric Map Number 5

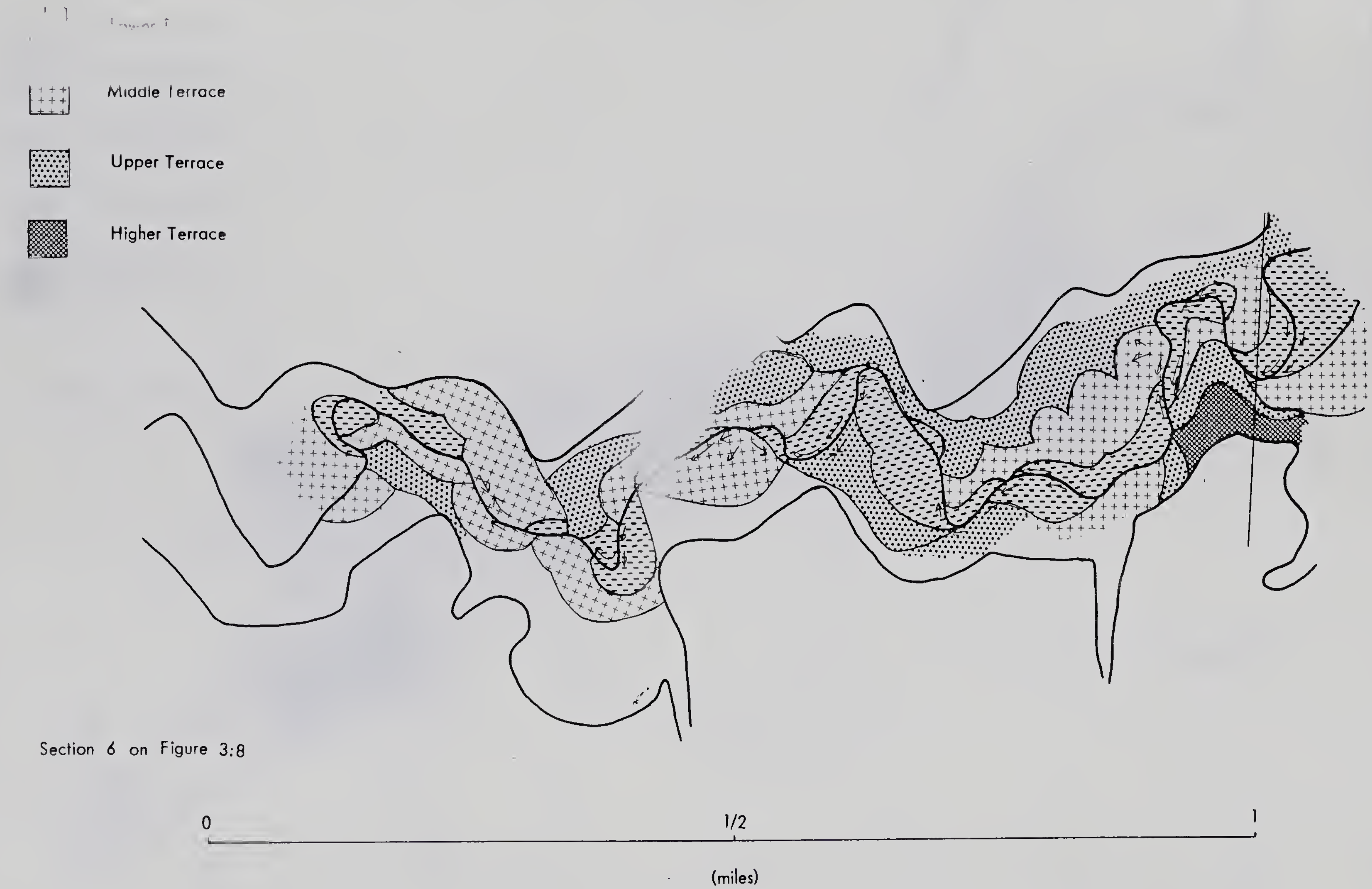
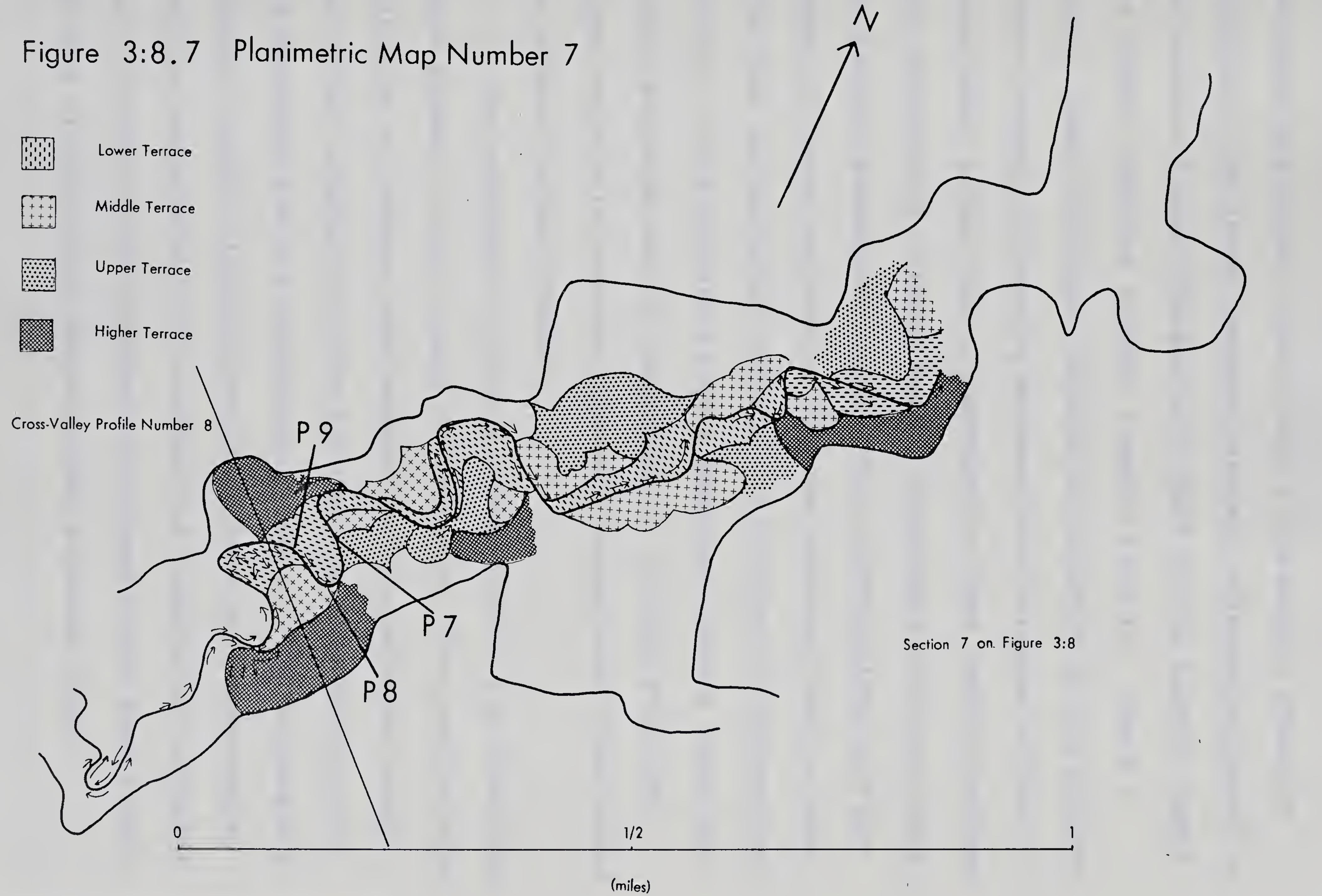


Figure 3:8.6 Planimetric Map Number 6

Figure 3:8.7 Planimetric Map Number 7



the upper and higher levels more infrequently shown as expected. The lower terraces are all situated adjacent to the present stream channel with most of the middle, upper and higher terraces further removed from it. Where a middle, upper or higher terrace is adjacent to the present stream channel, it can be assumed that terraces of the lower level either did not develop in that section or have been subsequently eroded away. Proceeding upstream along the present meandering channel from cross-valley profile number 4, lower and middle terraces show up first on one side then on the other depicting a picture of terrace continuity. This pattern is less distinct for the upper and higher terraces but is discernible. In many sections, lower and middle terraces directly oppose each other along the present stream channel.

The evidence of terrace continuity in the Weed Creek basin appears to be clearly established. The profile distribution of bedrock and terrace heights patterns along the valley coupled with the planimetric distribution of the terraces are the supporting factors. The terrace and bedrock heights distribution along with the cross-valley profile patterns and the statistical results all indicate that the Weed Creek terraces are grouped into four levels and are of the cyclic depositional alluvium type.

CHAPTER IV

REGIONAL CORRELATION AND GEOMORPHIC INTERPRETATION OF THE WEED CREEK BASIN

The interpretation of the Weed Creek terraces appears to support the general post-glacial geomorphic history developed for the North Saskatchewan river basin system. The similarities of terrace percentage-heights and groupings into several levels between the Weed Creek, Whitemud and North Saskatchewan river basins in the Edmonton area, suggests, as there should be, an inter-connection between them. Rains (1969) has proposed a post-glacial geomorphic relationship between the terraces of Whitemud and North Saskatchewan river basins near Edmonton, based on their grading evenly into each other at the confluence and their relative elevations. The association of the Weed Creek terraces with those of the Whitemud basin is closely linked on the basis of percentage-heights, terrace deposit thicknesses and geologic structure. A parallelism also exists between the Weed Creek and North Saskatchewan terraces founded on percentage-heights and geologic structure.

Geomorphological research has been done in the Red Deer (McPherson, 1968) and Bow Valley (Stalker, 1968) basins. Westgate (1969) has implied a link between the North Saskatchewan and Bow Valley terraces based on heights and faunal remains within the two basins. Certain char-

acteristics between the three basins indicate that future research into the regional post-glacial geomorphology should be considered.

Correlation of the Weed Creek Terraces

The correlation of the Weed Creek terraces is based on the classification and geologic structure of the terraces, the terrace percentage-height distribution and the terrace continuity. There are four major cyclic terrace levels within the basin. A stable non-rejuvenating section between cross-valley profiles 4 to 8 (Fig. 3:1) was chosen for detailed study. The bedrock heights within this section showed a grouping into four different levels. The levels, based on percentage-heights of the valley depth, are 45 - 52, 27 - 36, 17 - 21 and 5 - 11. Because such bedrock heights represent the bed levels of former stream channels, they are considered a very definite and reliable marker and as such form the basis of the terrace correlation.

The terrace levels were then delimited by adding the average thicknesses of the terrace deposits in each level to the related bedrock heights. The deposit thicknesses were first converted to percentage-height relationships. The four terrace levels established were 68 - 74, 44 - 56, 31 - 37, and 11 - 21.

Both the Weed Creek and Whitemud basins are similar in size, geology, geomorphology and climate. The Whitemud

terraces should then provide an excellent measure for comparison of the Weed Creek terraces. Table 4:1 shows the close similarities between the two basins. The terrace percentage-height levels when statistically treated by the Student-t method through comparisons of the Weed Creek terraces and cross-valley profiles with those of the Whitemud terraces, shows no significant differences at the 10% confidence level. The exceptions are the significant differences between the means of the Weed Creek terrace numbers 67 and 51 (Table 3:3, numbers 5 and 9). This significant difference is found in that section of stream down valley from cross-valley profile number 4. Several relatively large tributaries enter the main stream in this section. Gooding (1957) states that for a small stream, the variations in water volume and load contributed from its tributaries would be the only major cause of local variations and adjustments in the hydraulic factors along the main stream's course; any tectonic or climatic change would likely affect the whole drainage basin. This may explain the presence of the 'low' terraces within the rejuvenated section of the stream below the 10 percentage-height level. When these terraces are incorporated into statistical tests (terrace number 67), they account for the significant difference between the number 67 and number 51 terraces. Otherwise the terrace statistics show a non-significant difference relationship. Then on the basis of bedrock

TABLE 4:1. Terrace Percentage-Height Distribution

	Higher Level	Upper Level	Middle Level	Lower Level
Weed Creek	68-77	44-56	31-37	11-21
Whitemud Creek	66-73	45-57	30-38	13-22
North Saskatchewan	75	50	30-35	10-15

height distribution including comparison with the Whitemud terraces, the Weed Creek terraces are grouped into four levels. Rains (1969) finds that the Whitemud terraces are cyclic. This implies cyclic significance for the Weed Creek terraces.

Four additional criteria for cyclic significance were also satisfied. First, the thicknesses of the terrace deposits for each of the levels have means with small standard deviations and as such, their mean thicknesses are representative of the even-thickness distribution of the deposits (Table 3:2). Also, the deposit thicknesses provide a range within which terrace heights may fluctuate within each level. Second, the terrace tread surfaces are mainly horizontal. This was observed in the field and is also well expressed in the cross-valley profiles (Fig. 3:3.1 -3:3.8). Third, the former longitudinal stream profiles are generally parallel to each other and to the present stream channel (Fig. 3:5.1-3:5.2 and 3:6.1-3:6.2). Fourth, the out-of-phase pattern of high and low terrace heights for the left and right sided terraces in each level strongly

suggest a meandering condition when lateral and vertical accretion processes are in progress. This condition is necessary between periods of degradation for the cyclic development of terraces.

Throughout the length of the valley, the terrace deposits reveal an upward fining sequence with stream gravels lying on well demarcated bedrock flats. Never at any point along the stream were any contemporaneous gravels found lying discondantly above the alluvial deposits. This indicates that the terraces were not cut from deposits previously laid down at some earlier stage and then carved out, but that the deposits were laid down immediately before a change of regime was initiated to cause the formation of the terraces. The terraces then are of the depositional type. In all cases examined, the terrace cuts showed them to have an alluvial type depositional structure. The Weed Creek terraces, then, are cyclic and depositional with an alluvial geologic structure.

Correlation of the Weed Creek terraces by height shows four established levels. The bedrock heights (Fig. 3:5.1-3:5.2) are so distributed that the old channel profiles for the lower, middle and upper levels are clearly expressed; the higher level profile has been tentatively drawn; heights are too few to properly establish its level. Each of the old channels displayed in the cross-valley profiles fits into one of the well-defined bedrock levels.

Further, the four terrace levels established by adding the average thicknesses of the terrace deposits to the bedrock height levels are also well defined. The related terrace treads of the cross-valley profile channels fit mainly into the terrace levels associated and related to their particular bedrock levels. Again, the very close similarity of terrace percentage-height levels with those of the Whitemud basin along with their close proximity clearly indicates that the terraces of both basins share similar hydrologic, geologic and geomorphic histories.

The terrace continuity correlation is also well established. The lower and middle terraces between the cross-valley profiles 4 to 8 are numerous and widely distributed but close or adjacent to the present stream channel. The planimetric distribution of these levels can be easily traced up or down valley (Fig. 3:8.4 - 3:8.7). Where a particular terrace of one of these levels does not have a similar directly-opposing complementary terrace, it can invariably be traced immediately upstream or downstream since the meandering nature of the stream very seldom, if ever, erodes a set of paired terraces simultaneously from both sides. The same continuity pattern is discernible, but not as clear, for the upper and higher levels though the terraces are, in most cases, not adjacent to the present stream channel. They are present as infrequent discrete remnants.

The continuity pattern of the four terrace levels is also clearly established in profile (Fig. 3:5.1-3:5.2 and 3:6.1-3:6.2). The continuous nature of the terraces is depicted in the alternating high terrace tread-low channel bed pattern distributed longitudinally for each level. Because the lower and middle level terraces are more numerous than the upper and higher levels, the wave-like longitudinal pattern has shorter wavelengths. Without the continuity distribution pattern of the bedrock and terraces, the old channel profiles and their generally parallel character would not be easily discernible. Continuity forms the basis of terrace correlation and it is because of the bedrock and terrace continuity distribution pattern that the establishment of the bedrock and terrace levels were made possible.

Comparison of the Weed Creek and Whitemud Creek Terraces

Percentage hypsometric curves for both the Weed Creek and Whitemud basins were compared (Fig. 4:1). The curves indicate that both basins are in the equilibrium stage (maturity) of development (Strahler, 1952). The similarity of curvature makes them of the same family and suggests that the hydrological, erosional and sedimentation histories of the basins are similar. The first point to support this observation is the closely related terrace

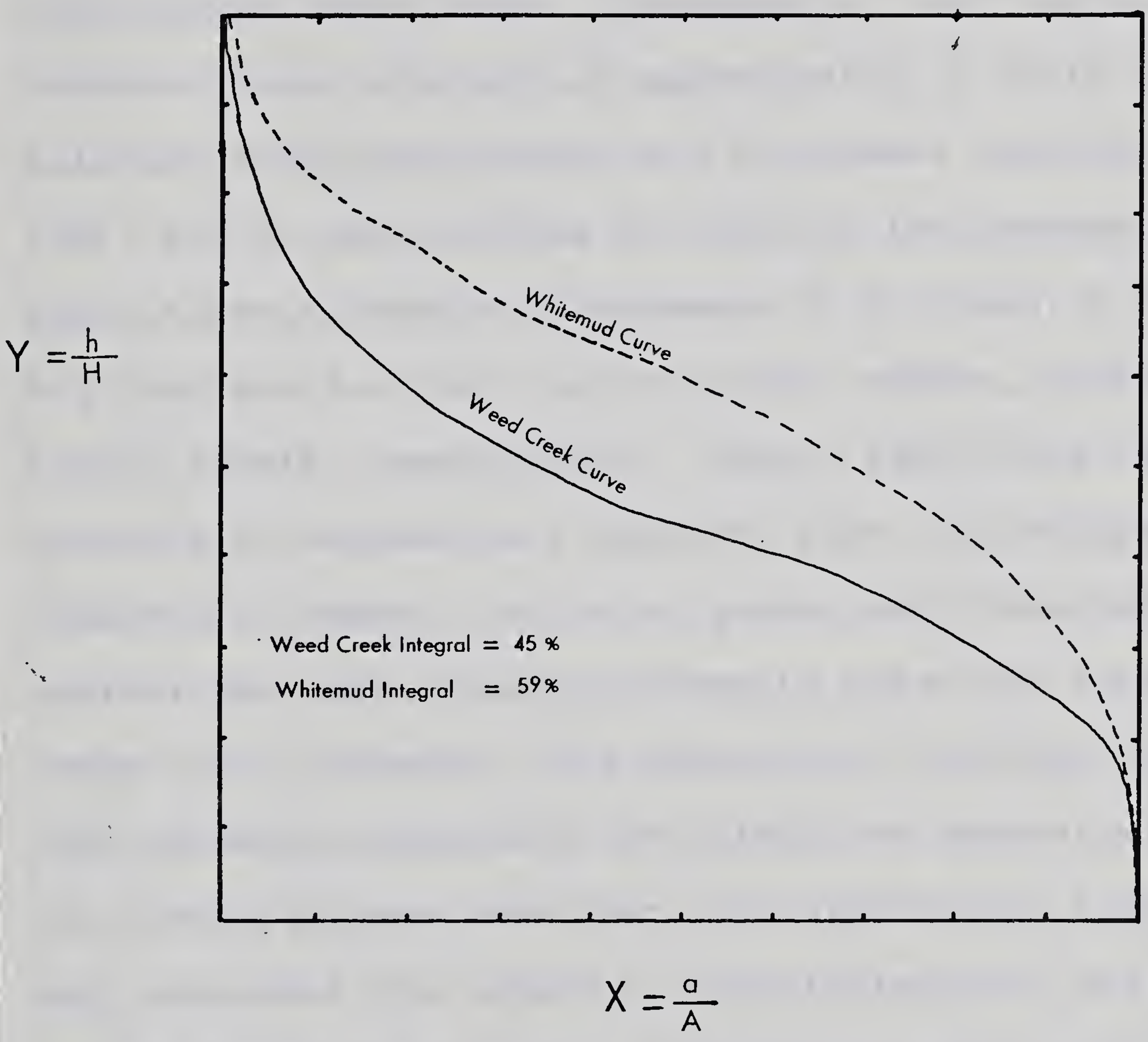


Figure 4:1 Percentage Hypsometric Curves - Weed Creek and Whitemud Basins

levels (Table 4:1). Also, the present channel profiles are almost identical in expression (Fig. 3:1 and 3:2) with the lower sections showing signs of rejuvenation. The middle sections are more stable with similar and more gentle gradients--a reflection of homogeneous geological and hydrological conditions. Furthermore, each terrace of the Whitemud basin consists of approximately 5 to 10 feet of alluvium overlying bedrock or Pleistocene deposits (Rains, 1969) and is very similar in range to the average Weed Creek terrace deposit thicknesses of 6.3 feet, 6.3 feet, 6.7 feet and 7.4 feet for the lower, middle, upper and higher levels, respectively. Rains (1969) also notes that numerically dominant are sections with a stratigraphic sequence of bedrock, alluvial gravel and fine-grained alluvium; the same sequence generally holds for each of the three lower terraces. The sequence of the Weed Creek terrace deposits observed in the field are generally the same but more rigourous laboratory and statistical testing would help determine the extent of the similarities and differences between the levels. In addition, the tread surfaces of the Whitemud terraces are generally horizontal and many old meandering channels are clearly visible from aerial photographs (Rains, 1969). The cross-valley profiles of the Weed Creek basin also show horizontal tread surfaces. Finally, the bedrock and terrace profile diagrams (Fig. 3:5.1-3:5.2 and 3:6.1-3:6.2) exhibit some overlapping and

non-cyclic terraces. Rains (1969) has found some non-cyclic terraces in the Whitemud basin and notes that occasional extreme floods have occured in recent years because at least one middle terrace site exhibits evidence of very recent aggradation, 15 feet above the present channel. Floodwaters during the month of July, 1973, after intensive rains for two days, rose to at least 10 feet above the present stream channel in Weed Creek.

Rains (1969) found no contemporaneous terrace deposits lying discordantly on tread surfaces and notes that the paired terraces of the Whitemud valley cannot be reconciled with the concept of a major valley fill being subsequently trenched to form various terrace levels; rather, a number of degradation phases were interspersed with periods of aggradation. This fact along with the terrace deposit stratigraphic sequence makes the Whitemud terraces depositional and of alluvial origin.

Both basins are of similar size and north flowing tributaries of the North Saskatchewan river within a few miles of each other. Their erosional, hydrological and sedimentary histories are in close agreement as reflected in the comparable terrace levels, terrace deposit thicknesses, channel profiles and horizontal tread surfaces. Both sets of terraces are cyclic, depositional and alluvium. Correlation between the basins are positive and therefore share similar geomorphic histories.

Comparisons with the North Saskatchewan River --Edmonton Area

Westgate (1969) has identified four post-glacial alluvial terraces in the North Saskatchewan river within the city limits of Edmonton, Alberta. They are at 20 - 30 feet, 60 - 70 feet, 100 feet and 150 feet, approximately, above the present stream level and cut in a valley of 200 feet depth. Their percentage-heights are closely related to those of the Weed Creek and Whitemud basins (Table 4:1). Though the Weed Creek basin is a tributary of the North Saskatchewan river and therefore of much smaller scale, the percentage-height relationship of their terraces suggests a synchronous hydrologic, erosional and sedimentary history.

Rains (1969) states that there is little reason to doubt that the Whitemud and North Saskatchewan terraces are intimately related. The lower Whitemud terrace grades evenly into the lowest unit recognized by Westgate (1969), and the higher ones are consistent in terms of relative elevation (Fig. 3:4). No comparison of the related stratigraphies was attempted since the two rivers are of widely disparate size. It seems clear that the Weed Creek basin terraces and the North Saskatchewan terraces near Edmonton are closely related.

The history of the North Saskatchewan River is characterized by alternating periods of degradation and

aggradation that were most probably controlled by fluctuations in the position of the Laurentide ice front to the north-east of the study area (Westgate, 1969). Stratigraphic investigations of the lower two terraces show them to be of the alluvial type (Westgate, 1969). The general upward fining of the deposits in the lower two terraces along with the absence of contemporaneous deposits resting on their tread surfaces indicate that the terraces are truly depositional in mode of formation. Fig. 4:2 displays the North Saskatchewan terrace treads as being horizontal (after Westgate, 1969). The same pattern is observed in the field for those terraces preserved along the river banks within the city limits of Edmonton. This suggests that the terraces are cyclic. The cause of the North Saskatchewan terraces is climate, effecting base-level control. Preglacial ponding and degradation would be favoured at times of glacier retreat of the Wisconsin Laurentide ice sheet (Frye, J.C. et al, 1968; Westgate, 1969), a condition sufficient for cyclic development of terraces.

Post Glacial Chronology of the Weed Creek Basin

The Weed Creek, Whitemud and North Saskatchewan terraces are all closely associated. The geomorphic chronologies for the three basins are similar. Climatic control is believed to have been the cause of the North Saskatchewan River terraces. The alternating periods of degrada-

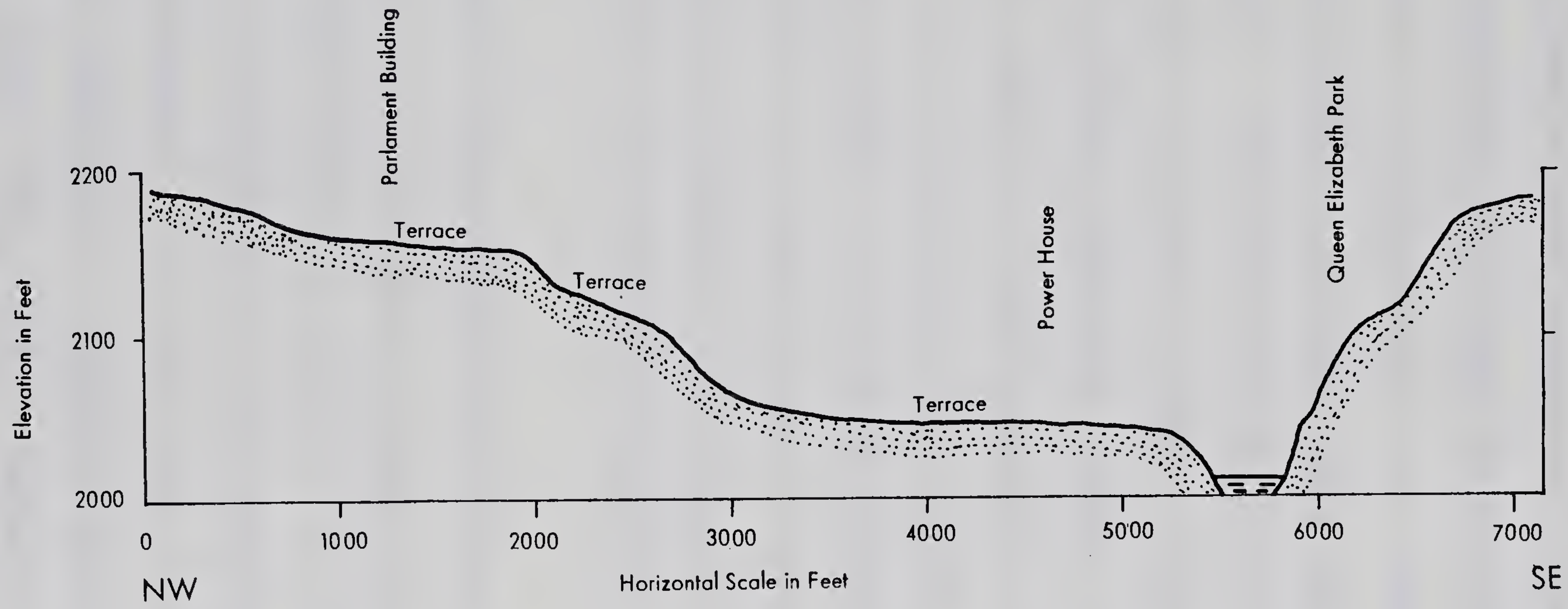


Figure 4:2 Postglacial Terraces of the North Saskatchewan River at Edmonton

After Westgate, 1969

tion and aggradation within the basin indicates that the direct control of terrace formation in both the Whitemud and Weed Creek basins must have been base-level fluctuations. If, therefore, the North Saskatchewan river valley was cut entirely in post-glacial time (Westgate, 1969), the Weed Creek terraces too must have been cut during the same time period. The North Saskatchewan's lower terraces formation spanned the period 8,500 to 5,000 years BP based on a change in climate (GSC-767; Lowden and Blake, 1968) and Mazama ash, dated at 6,600 years BP, found at depths varying from 4 to 8 feet below the surface of the terrace (Westgate et al, 1969). The middle terrace has been estimated about 10,000 to 11,000 years BP based on the uncertain correlation of similar fauna found in a 65 foot terrace in the Bow Valley near Cochrane (Churcher, 1968; Stalker, 1968).

An extinct bison scapula was found in the Weed Creek basin just upstream from cross-valley profile number 2. (See Photo Plates 5 and 6.) It has been dated by 14C technique at 2765$\pm$90 14C yr BP (Radiocarbon Dating Laboratory, Saskatchewan). It was found in the deposits of a 15 foot terrace embedded in rippled sands 12.5 feet above present stream level (Fig. 3:8). Bedrock is at 9.5 feet. The fossil fauna was overlain by 3 feet of fine sands and a juvenile soil 1 foot deep. The valley depth at this point is 118 feet and fits into the lower terrace level

interval of both the Weed Creek and North Saskatchewan terraces (Table 4:1). The reconciliation of the two dates for the lower terrace levels of both basins is suggested. Terraces that are formed by base-level control are usually initiated first at the mouth of the stream. Such features, of base-level control, in a tributary stream such as the Weed Creek basin, would probably form somewhat later than their related terrace in the trunk stream. If this were true, then the Weed Creek lower terrace level would be associated with the same aggradation-degradation cycle of the North Saskatchewan lower level terrace. Further finds of faunal remains and Mazama ash, especially within the 4 to 8 cross-valley profile section of the basin could confirm the explanation. The middle, upper and higher terraces then are older than 2765±90 years BP. Their ages should be relatively younger than their related terraces in the North Saskatchewan River basin.

Considerations for a Regional Correlation

A regional correlation is not being proposed but there are points that should be of value if such a correlation is to be considered. Stalker (1968) investigated a series of terraces in the Bow Valley near Cochrane, Alberta. Two sets of terraces--upper and lower--were discovered, each with distinct differences in composition, origin and time of deposition. The lower set of terraces have four distinct

heights, the same number found in the North Saskatchewan River system. The terraces are of post-glacial origin cut mainly by fluvial action. Similar faunal remains have also been found in the terrace deposits of both river systems. Though the lower set of terraces were cut from a previous fill--the Bighorn Creek Formation--the aggradation of significantly thick layers of sand and thin layers of silt overlying the coarser poorly sorted sands and gravels and bedrock in some sections, makes the terraces depositional and alluvial in mode of formation and geologic structure. The terrace tread surfaces are distinctly smooth and horizontal with a gradient similar to that of the present stream channel. This implies that the terraces are probably cyclic in origin. Stalker (1968) suggests that the cutting of these terraces started about 10,000 years ago and still continues.

In the Red Deer river, McPherson (1968) found sequences that appear similar to both the North Saskatchewan river system and the Bow Valley river. Two sets of terraces--upper and lower--were also discovered with a distinct difference in composition, origin and time of deposition. The lower set of terraces are of fine-grained alluvium--sands, silts and clays--whereas the upper set are of poorly sorted sands and gravels. There is evidence that the lower set has, as their base, the deposits from which the upper set are formed with some sections on bed-

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rock, but the thickness and sequence of the fine grained alluvium suggests that the lower set of terraces are depositional and alluvial. In the Bow Valley, Red Deer, Whitemud and Weed Creek basins, the alluvial deposits for all the terraces, irrespective of height are generally similar to the deposits of their respective floodplains. McPherson (1968) proposed that the lower set of Red Deer terraces are non-paired on the basis that two terraces, opposing each other across the present stream, have a difference in height of six feet. He also indicates that the terrace tread surfaces are strikingly flat, horizontal and smooth. Paired terraces do not have to be exactly equal in height since several processes could cause differences in their heights (Chapter II, p. 36). A six foot difference in height between directly opposing terraces found in a river basin the size of Red Deer is not convincing evidence that the terraces are non-paired. On the basis of the flat horizontal and smooth nature of the terraces along with the alluvial stratigraphy, it might be possible that the lower set of Red Deer terraces are also cyclic in origin, but further investigation is required.

Young juvenile soils are present on the Red Deer, Whitemud and Weed Creek terrace treads and also their smooth undistrubed surfaces imply that they were all formed in very Recent times. A final note is that the bedrock geology in all three river systems is similar--that of Tertiary and Late Cretaceous sandstones and shales.

Summary

Four terrace levels are identified in the Weed Creek basin based on bedrock heights, terrace heights, cross-valley profiles and the planimetric and profile continuity terrace distributions. The middle, upper and higher levels are older than 2765 ± 90 years BP based on C14 dating of an extinct bison bone in the lower terrace level. The Weed Creek basin has developed synchronously with the Whitemud basin as seen in the remarkable close relationship of their terrace percentage heights, similar stream profiles, and even-distributed terrace deposit thicknesses. Along with sharing homogeneous geology and climate, both are comparable-sized tributaries of the North Saskatchewan River. This suggests that they both share the same hydrological, erosional and sedimentary histories. The Weed Creek higher terrace level establishment supports the argument for a fourth level terrace development within the North Saskatchewan river system.

The four terrace levels in the North Saskatchewan river, Edmonton area, correlate in percentage heights with the Whitemud and Weed Creek terraces as well and indicate that the direct external cause of the Whitemud and Weed Creek terraces is base level control by the North Saskatchewan river basin. The terraces of all three basins are cyclic in external cause, depositional in mode of formation and alluvial in internal composition. Evidence found

in the North Saskatchewan river system, Red Deer and Bow Valley rivers suggests that there is need for more extensive and intensive research to adequately decipher the post-glacial geomorphic history of the Western Canadian Plains.

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